THE NICKEL BULLETIN

A SUMMARY OF CURRENT INFORMATION ON NICKEL

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TYPICAL APPLICATIONS OF SPHEROIDAL-GRAPHITE CAST IRON

DURING the last four years, castings for every branch of engineering have been made in spheroidal-graphite cast iron. The list given below includes items mentioned in the extensive literature on the subject, and although far from complete, it is published here for the guidance of engineers and designers to indicate the types of use for which S.G. iron is proving suitable.

According to the properties desired, castings in S.G. iron are used either in the '*as cast*' state when the matrix is either pearlitic or a mixture of pearlite and ferrite according to the composition and section thickness, or '*annealed*' to the ferritic state. The castings may also be chilled to provide hard faces for wear-resistance and may also be alloyed and/or heat-treated to provide modified matrix structures, such as the martensitic, acicular and austenitic types, to meet special requirements. Such irons would include Ni-Hard where any grey iron backing would contain spheroidal-graphite, and Ni-Resist, Nomag, etc., in which the graphite is spheroidal.

This list is classified under some of the main engineering industries. Numerous uses of S.G. iron are of course common to several fields.

AGRICULTURE	
Tractor Parts	
Frames	As cast, or annealed
Support Brackets	Annealed
Front Wheel Forks	,,
Wheel Hubs	,,
Transmission Housings	,,
Lift Arms	,,
Crawler Track Links	As cast
Plough Parts	
Saddles	Annealed
Hitches	,,
Ploughshares	As cast, or annealed; chilled edge
Cultivator Blades	Annealed
Tail Wheel Brackets	,,
Mowing Machine Parts	
Frames	As cast, or annealed
Knife Holders	Annealed
Knife Guards	,,
General Parts	
Brackets	Annealed
Levers	,,
Worm Wheels	As cast
Gears	As cast, or annealed*
Pinions	,, ,, ,,
Cams	,, ,, ,,
Dog Clutches	,, ,, ,,
Diesel, Oil and Petrol Engine Details	See 'Engines I.C.'

AUTOMOBILES (see also 'Engines I.C.')	
Clutch Bodies	As cast, or annealed
Clutch Plates	As cast
Gear Boxes and Housings	Annealed
Gear Carriers and Straps	,,
Gear Selectors (Wilson)	,,
Pedal Levers	,,
Wheel Hubs	,,
Brake Drums	As cast, or annealed
Brake Shoe Segments	Annealed
Brackets	,,
Hydraulic Cylinders and Rams for Dump Trucks	,,
Bicycle and Motorcycle Frame Lugs and Brackets	,,
Jack Bodies	,,
Hydraulic Jack Cylinders and Rams	As cast, or annealed
Tyre Moulds	,, ,, ,,
Tyre Fitting Machines	Annealed

CHEMICAL PLANT	
Caustic Pots	As cast
Catalyst Support Grids	Annealed
Pumps	As cast, annealed, or austenitic
Valves	Annealed, or austenitic
Paddle Mixer Arms	,, ,, ,,
General Castings	Pearlitic—as cast, annealed, or austenitic
Bubble Caps	Annealed, or austenitic

ELECTRICAL	
Motor Parts	
Bodies and Frames	Annealed
Mounting Brackets	,,
Fans	,,
Brush Holder Brackets	,,
Generator Shafts	As cast
Generator End Plates	Nomag—or Ni-Resist
Armature Spiders	Pearlitic—as cast, or annealed
Trolley Wire Brackets and Fittings	Annealed; sometimes galvanized
Resistance Grids	As cast, or austenitic
Switch Gear Parts	Annealed
Circuit Breaker Parts	,,
Light Fittings and Hardware	,,

*Gears—Cast Teeth or Machined. According to service and size, gears are used as-cast or annealed or after heat-treatment, e.g., flame hardening.

Lighting Suspension Links	Annealed—galvanized
Lamp Guards for Airports	Annealed

ENGINES (I.C.)

Frames and Bodies	As cast, or annealed
Crank Cases	„ „ „
Cylinder Liners	As cast
Cylinder Heads	As cast, or annealed
Pistons	„ „ „
Piston Rings	As cast, or special compositions
Crankshafts	As cast
Timing Gears,	As cast. or annealed
Camshafts	As cast; chilled noses
Rocker Arms	Annealed; chilled pads
Fuel Injector Bodies	Annealed ; locally heat-treated
Exhaust Manifolds	Annealed
Flywheels	As cast, or annealed
Flywheels for Motor Cycles	Annealed
Starter Housings	„

GAS, WATER AND SEWAGE

Gas and Water Pipe—centrifugally cast	Annealed
Pipe Elbows and Fittings	„
Pipe Joints and Clamps	„
Pipe Specials	As cast, or annealed
Manifolds	„ „ „
Pipe Couplings	Annealed
Nuts and Bolts for Buried Pipelines	„
Tank Cover Clamps	„
Communitor Drums (Sewage)	As cast
Pipe Dies	„

HAND TOOLS

Spanners	Annealed
Handtools	„
C. Clamps	„
Gauges	As cast, or annealed
Airhose Couplings	Annealed
Handtool Frames	„
Brace Parts	„
Pneumatic Tool Bodies	„

HEAT-RESISTING PARTS (see also 'Metallurgical')

Furnace Grates and Bars	As cast, or annealed
Furnace Doors and Frames	„ „ „
Charging Hole Doors (coke ovens)	„ „ „
Burner Bodies	Annealed
Annealing Grids	„
Annealing Supports and Covers	„
Annealing Pots	„
Soaking Pit Covers and Supports	„
Hearth Plates	„
Flue Dampers	„
Furnace Skids	„
Stove Parts and Tops	As cast, or annealed
Tuyeres	„ „ „
Tube Supports and Superheater Spacers	Annealed
Glass Moulds	„
Glass Mould Plungers	„

HEAVY MACHINERY

Hydraulic Press Parts	
Cylinders	As cast
Rams	„
Heads	„
Nuts for Standards	„
Frames and Standards for Presses and Hammers	„
Steam Hammer Parts	
Heads	„
Cylinders	„
Guides	„
Blocks or Anvils	„
Forging Press Parts	
Cylinders	„
Heads	„
Pistons	„
Stamp and Press Beds	„
Stamp and Press Guides	„
Press Yokes	„
Press Cranks	„
Plastic Extrusion Press Cylinder	Annealed
Plastic Extrusion Press Worm	„
Cement Roll Shells	As cast
Cement Mill Gears	„
Road Making Machine Details	Annealed
Hydraulic Rams and Cylinders	As cast
Bearing Boxes, Blocks, Housings and Pedestals	As cast, or annealed
Large Gears	As cast*
Flywheels	„
Pulleys	As cast, or annealed
Rope Sheaves	„ „ „
Fan Hubs	„ „ „
Name Plates	Annealed

LIGHT MACHINERY

Cash Register Frames	Annealed
Typewriter Frames	„
Textile Machine Parts	
Levers	„
Cams	„
Gears	„
Links	„
Thread Guides	„
Picking Buffers	„
Picking Eccentrics	„
Lever Guides	„
Roller Ends	„
Lawn Mower Castings	„
Parts for Domestic Equipment such as Gears and Racks for Washing Machines, Food Handling Equipment, etc...	As cast, or annealed
Laundry Ironer Beds	„ „ „
Rubber Goods Moulds	„ „ „

MACHINE TOOLS

Beds, Saddles, etc.	As cast
Chuck Bodies	As cast, or annealed
Clutch Bodies and Plates	„ „ „
Gears and Racks	As cast*
Cams, Templates	As cast

*Gears—Cast Teeth or Machined. According to service and size, gears are used as-cast or annealed or after heat-treatment, e.g., flame hardening.

Tool Blocks	As cast, or annealed
Tool Holders	„ „ „
Tool Shanks	„ „ „
Cutter Heads	As cast
Die Plates	As cast, or annealed
Press, Dies and Tools	As cast, or heat-treated
Vice Frames and Jaws	Annealed
Grinding Wheel Guards	„

MARINE

Circulating Pumps	As cast
Feed Pumps	Austenitic, or acicular
Propellers	As cast
Porthole Frames and Covers	Annealed
Side Fittings	As cast, or annealed
Deck Machinery Details	„ „ „
Capstans	As cast
Bollards	„
Pile Points	As cast, or annealed

METALLURGICAL (see also 'Heat-Resisting')

Melting Pots for Al and Pb	As cast, or annealed
Anode Clamps and Holders	„ „ „
Slag Pots	„ „ „
Moulding Machine Cylinders	As cast
Moulding Boxes	Annealed
Moulding Box Clamps	„
Centrifugal Casting Dies	„
Centrifugal Casting Die Holders	„
Die Casting Machine Parts	
Pots	As cast, or annealed
Goose Necks	Annealed
Dies	As cast, or annealed
Ingot Moulds for Non-Ferrous Metals	As cast, or annealed
Hot Tops for Ingot Moulds	Annealed
Billet Moulds for Cu.	As cast, or annealed
Pig Moulds for Bronze, etc.	„ „ „
Rolls—Densened	As cast; alloyed
Rolls—Grain	„ „
Run-out Table Rollers	As cast
Table Roller Bearings	„
Guides for Bar Rolling Mill	„
Forging Dies and Tools	„
Pipe Forming Dies	„
Piercer Points	„
Piercer Point Guides	„
Collapsible Mandrels for Strip Coiling	„
Flanges for Strip Coiling	„
Sintering Machine Boxes and Grate Bars	As cast, or annealed
Sintering Machine Pallets	„ „ „
Digger Teeth for Sandslinger	As cast
Lead and Salt Baths and Pots	As cast, or annealed

MINING

Mine Cage Guides	Annealed
Winder Drums	As cast
Large Brake Drums	„
Pump Connecting Rods	Annealed
Pump Details	As cast, or annealed
Car Wheels	As cast; chilled
Coal Conveyor Sprockets	As cast
Coal Crusher Gears	„
Ore Chute Liner Plates	As cast, or annealed; chilled
Ball Mill Liners	As cast; chilled
Tube Mill Gears and Rollers	As cast
Crusher Frames	„

PAPER AND PRINT

Beater Shafts	As cast
Dryer Cylinders	„
Jordan Plugs	„
Press Roll Bodies	„
Paper Machine Gears	„*
Printing Machine Gears, Levers, etc.	As cast, or annealed
Printing Machine Rolls	„ „ „

PETROLEUM

Drilling Rig Rocker Bearings and Saddles	As cast
Pumps	As cast, or annealed
Valves	Annealed
Fittings	„
Bubble Caps	„
Stair Treads	„
Tanker Pipes and Fittings	„

POWER (see also 'Engines I.C.' and 'Electrical' and 'Heat-Resisting')

Water Turbine Casings	As cast
Steam Turbine Casings (low press)	„
Turbo-Compressor Shell	„
Turbine Bearing Pedestals	„
Turbine Base Plates	„
Compressor Parts	
Bodies	As cast, or annealed
Heads	„ „ „
Frames	„ „ „
Cylinders	As cast
Pistons	As cast, or annealed
Crankshafts	As cast
Couplings	As cast, or annealed
Bearing Shells	Annealed
Valve Bodies	„
Feed Pump Bodies	Austenitic, or acicular
Flywheels	As cast
Chain Sprockets	„
Gear Wheel Centres and Spiders	„

RAILWAY AND TRAMWAY

Axle Boxes	Annealed
Worms and Gears for Railcars	As cast
Traction Motor Supports and Bearing Plates	Annealed
Roller Bearing Boxes	„
Roller Bearing Box Liners	Acicular
Bearing Blocks	As cast, or annealed

*Gears—Cast Teeth or Machined. According to service and size, gears are used as-cast or annealed or after heat-treatment, e.g., flame hardening.

ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Equipment for Thermal Treatment: Institute of Metals Symposium

'Symposium on Equipment for Thermal Treatment of Non-Ferrous Metals and Alloys.' *Jnl. Inst. Metals*, 1952, vol. 80, Feb., pp. 255-339.

The following papers were contributed to the Symposium, which was held as part of the Annual Meeting of the Institute, in London, during March, 1952.

C. J. EVANS, P. F. HANCOCK, F. W. HAYWOOD and J. MCMULLEN: 'Electric Furnaces for the Thermal Treatment of Non-Ferrous Metals and Alloys.' *Paper* 1347; pp. 255-67.

An introductory paper, reviewing the types of furnace available for the thermal treatment of (1) light alloys, and (2) copper, nickel and their alloys. The review includes reference to controlled atmospheres suitable for treatment of the respective materials. Particular attention is directed to the usefulness of furnaces of specialized design which work in conjunction with conveying or handling gear, thus forming part of continuous production lines.

J. F. WAIGHT: 'Gas Equipment for the Thermal Treatment of Non-Ferrous Metals and Alloys.' *Paper* 1348; pp. 269-85.

The reasons for the popularity of town's gas as a fuel in the non-ferrous metals industry are briefly considered, and methods of heat-transfer operating when this heating medium is used are discussed. The next section of the paper reviews the burner systems in common use in the industry: emphasis is laid on the importance of automatic mixture-control devices, some of which are described in detail, with drawings. Furnace structure is discussed in relation to heat losses, and conditions requisite for efficient heating are indicated.

In connexion with furnace atmospheres, reactions of the various metals with the following gases must be taken into account: oxygen, carbon dioxide, water vapour, hydrogen, carbon monoxide, sulphur dioxide, hydrogen sulphide. Characteristic effects produced by all these gases are discussed, and the effects of sulphur-containing atmospheres are specially considered. In this connexion reference is made to the catalytic sulphur-removal plant developed by the North Thames Gas Board, by which sulphur can be reduced from 20-25 to 3-4 grains/100 cu. ft.: a photograph of this plant is given. Notes are added on the suitability of (*a*) partially burned town's gas, (*b*) cracked ammonia, and (*c*) burned ammonia, for individual metals and alloys.

The final section of the paper contains a description of typical gas-fired furnace installations, illustrating the application of various burner systems and the use of mechanical-handling equipment.

E. DAVIS and S. G. TEMPLE: 'Batch and Continuous Annealing of Copper and Copper Alloys.' *Paper* 1349; pp. 287-96.

Increasingly exacting requirements with regard to uniformity of crystal structure, physical and mechanical properties, and surface finish now regularly specified for copper-base alloy products, combined with a need for improved operating efficiency and increased output, have resulted, in recent years, in considerable changes in annealing equipment and practice for wrought copper and copper alloys. Some of the major features of recent development are described in this paper, and the information given is correlated with data on the annealing characteristics of representative copper-base alloys and with the influence, on such characteristics, of composition, and impurities. In addition to annealing treatments carried out for the softening of such materials, consideration is given to other forms of heating, e.g., stress-relief annealing, solution heat-treatment, and temper-hardening treatments.

Various types of batch and continuous furnace are described, the factors influencing uniformity of annealing are considered, and the relative merits, limitations, and applications of batch and continuous treatment are critically discussed.

Due to the readiness of copper-base materials to oxidize in air, much attention has been given in the industry to the development of protective atmospheres for use in annealing. The effects of various gases on these materials is summarized, and the use of steam atmospheres, atmospheres derived from ammonia, and atmospheres of fuel-gas derivatives, is described. Attention is directed to special problems arising from the zinc content of brasses, and to the conditions requisite for bright-annealing of these alloys.

H. J. HARTLEY and E. J. BRADBURY: 'Bright Annealing of Nickel and its Alloys,' *Paper* 1350; pp. 297-309.

This paper gives a brief history of the development of bright annealing as applied to nickel and nickel alloys, including an outline of the most important theoretical aspects of the subject, and describes typical equipment now in use for the large-scale bright annealing of wire, strip and sheet. In selecting conditions suitable for treatment of nickel and nickel-base alloys, the composition of the material treated, the affinity of each major component element for oxygen, the possible effect of minor elements, the effect of sulphur, and the effect of carbon must be considered. Each of these variables is discussed, as affecting the operating conditions which have been developed for nickel-chromium, nickel-copper-zinc, nickel-copper and other nickel alloys, as well as for the pure metal.

A detailed account is given of methods used for

bright annealing of nickel-chromium wire, and of the procedure for treatment of strip of nickel silver and other nickel-base materials. Diagrams of both wire- and strip-annealing furnaces are shown, and particulars are given of the circuit diagram of a photo-electric pyrometer controller developed for use with the strip-annealing unit. Reference is also made to belt-conveyor furnaces employed for sheet and wire annealing, and notes are given on the scope of their application.

In discussing atmospheres of controlled composition, special attention is directed to methods adopted for the production of sulphur-free atmospheres from town's gas, and to methods of testing the suitability of purging-gas atmospheres for use in annealing nickel-base materials. In the closing section of the paper some suggestions are made as to improvements still required in order to perfect bright-annealing equipment and processes.

C. P. PATON: 'Batch Thermal Treatment of Light Alloys,' *Paper* 1351; pp. 311-22.

The essential features of annealing, solution, precipitation and stabilizing treatments normally applied to light alloys are summarized, as an introduction to discussion of the factors affecting choice of furnaces for the respective operations. These are considered under the following headings: fuels, heating media, circulation of heating media, furnace atmospheres, temperature measurement and control, quenching and drying, general handling, and materials of construction. A description is given of various types of furnace with which operational experience has been obtained. The final section of the paper contains critical discussion of current batch-furnace design, with suggestions of modifications required to secure higher efficiency of working.

R. T. STAPLES: 'Flash Annealing of Light Alloys,' *Paper* 1352; pp. 323-34.

Although the principles and practice of flash annealing are not new, its application to the treatment of light alloys is of relatively recent date. Typical design of flash-annealing furnaces is described and their specific applications are indicated. A wide range of thermal treatments can be successfully accomplished by this means and the author urges that such flash-annealing furnaces represent an advance in technique over the batch-treatment type. The case for employing high rates of heating to secure fine grain size is theoretically discussed, and the conclusions drawn are supported by evidence secured in industrial practice. Factors governing the design of a single-sheet, conveyor-type furnace are reviewed, and performance data for such a unit are reported.

M. LAMOURDEDIEU: 'Continuous Heat-Treatment of Aluminium Alloys of the Duralumin Type,' *Paper* 1353; pp. 335-9.

Description of plant and results of tests on Duralumin-type alloy and 24S Alclad.

Identification of Metals and Alloys by Chemical Spot Testing

C. T. WILSHAW: 'The Identification of Metals and Alloys by Chemical Spot Testing.' *Metallurgia*, 1952, vol. 45, Feb, pp. 102-6. Corrigendum, *ibid.*, Mar., p. 153.

Many of the spot-testing procedures in current use are designed to determine the presence in, or absence from, a material of one specific element, rather than to distinguish between materials which contain several common elements. The procedure described in this paper is designed primarily for this latter purpose, as an aid to differentiation, for example, of the various corrosion-resisting materials which may be employed in oil refineries, chemical works or other plants in which a wide range of materials are in use, some of which are relatively akin, while others are totally different, in composition.

Following some general notes on precautions which must be observed in all chemical-spot testing, if reliable results are to be obtained, the author gives details of a series of reagent solutions, and methods for their application for identification purposes. The use of these solutions is then exemplified by means of a chart, for the purpose of identifying various metals and alloys. Materials which may be detected by the procedures described include carbon and low-alloy steels, ordinary and low-alloy cast irons, manganese steel, cupro-nickel, Hastelloy alloys, Monel, Ni-Resist, high-chromium and chromium-molybdenum steels, 18-8 and other austenitic chromium-nickel steels, chromium, nickel and Duriron.

An appendix gives details of specific spot tests for the determination of nickel, chromium, or molybdenum personally tested by the author.

Technique and Applications of the Salt-Spray Test

'The Salt-Spray Test.' *Metal Industry*, 1952, vol. 80, Feb. 15, pp. 123-6.

A survey of the origin of the test, its development, the type of equipment used, specifications covering its operation, and the uses of the test for inspection-control and laboratory purposes.

NICKEL

Magnetostriction Phenomena in Nickel

E. W. LEE: 'The Approach to Saturation Magnetostriction of Nickel.' *Proc. Physical Soc., Lond.*, Sect. B, 1952, vol. 65, Feb. 1, pp. 162-3.

Brief report of measurements of differential magnetostriction $(dl/dH)/l$ as a function of a steady applied field. Nickel was chosen in preference to iron because (1) the magnetostriction coefficient is somewhat greater than in iron, and (2) magneto-crystalline energy and the fields required to produce saturation are smaller. The specimen used was in the form of strip and was annealed in vacuo at 820°C. for four hours, followed by cooling at 100°C. per hour. The work was done in order to check the validity of the conclusion drawn by RÜDIGER and SCHLECHTWEG (*Ann. Physik*, 1941, vol. 39, p. 1) that in fields sufficiently

great to approach saturation magnetostriction should obey a law of the form $dl/l=(dl/l)_s-a/H$. The present authors' results do not confirm the general applicability of this equation. A fuller account of their work is to be published later.

Casting of Anodes for Electrodeposition of Nickel

H. CHASE: 'Casting Nickel Plating Anodes.' *Foundry*, 1952, vol. 80, Feb., pp. 204-5.

This note describes practice in the plant of Chevrolet-Flint Manufacturing Division of General Motors Corporation, where anodes are cast to supply the plating shops of the organization. Each heat contains 930 lb. of nickel, made up of cathode sheet of 99·98 per cent. purity and of scrap anode material. Charcoal is charged, to add carbon, and magnesium is used to scavenge the ladle. Furnaces are lined with sillimanite. The anodes produced are of 73-lb. weight and have a conventional rounded, but somewhat flattened, sectional shape. They taper towards the lower end, to facilitate removal from the moulds, which are made in two halves, held together by steel rings and wedges. Casting practice is described. Between heats the upper 18 in. of the interior of the mould, which attains the highest temperature, is given a coating of sillimanite, applied with a brush, a procedure which not only helps to protect the surface of the mould, but also assists in preventing the castings from sticking. As further safeguard against sticking, two carbon moth balls are dropped into each mould immediately before it is filled. The naphthalene smoke produced when the hot metal strikes the balls helps to coat the walls with carbon, and thus give protection. Pouring is at 2800°-3000°F. (1540°-1650°C.), and on solidification the castings are knocked loose and lifted to a quench tank, where they are cooled before being transferred to the nickel-lined tumbling barrel. Tumbling is continued only long enough to remove flash and sharp edges, after which the hook hole is drilled and tapped in the bottom end of the anode.

Metal Solution Potentials of Nickel in Foreign Ion Solutions

D. MACGILLAVRY, J. H. ROSENBAUM and R. W. SWENSON: 'Metal-Solution Potentials of Nickel in Foreign Ion Solutions and the Mechanism of Nickel Corrosion.' *Jnl. Electrochemical Soc.*, 1952, vol. 99, Jan., pp. 22-7.

Phase-boundary potentials of nickel in various aqueous solutions practically free from nickel ions were measured, in the presence, and with complete absence, of air. Special attention was given to possible interference by oxygen. The results show that the nickel-solution potentials in air drift, and reach high positive (noble) values. The potentials of nickel *vs.* solution in an inert gas reach stationary values after several hours, depending upon the pH. The final potentials remain negative with respect to the standard hydrogen electrode. The differences of the corresponding potentials in the same solution, in presence of air, or without air, range up to half a volt or more. Attention is directed to the interest in the rôle of oxygen in influencing the potentials, in relation to its bearing on the initial stages of corrosion of nickel.

Estimation of Boron in Boronized Nickel

G. H. BUSH and D. G. HIGGS: 'The Estimation of Boron in Boronized Metals.' *Analyst*, 1951, vol. 76, Dec., pp. 683-91; disc., p. 691.

Following a review of the more general methods used for separation of boron from associated elements, and for its estimation, the authors describe work carried out in adapting Tschischewski's method to the determination of boron in boronized iron, nickel, cobalt and copper. The metals named are removed by mercury cathode electrolysis. In addition, a method is reported for estimation of boron in boronized molybdenum, in which the molybdenum is separated as the sulphide. The boron, after conversion to mannitoboric acid, is finally determined by potentiometric titration with sodium hydroxide, which obviates the difficulties inherent in the use of colour-change indicators.

Nickel and Nickel-Alloy Coinage in India

'The Story of the Calcutta Mint.' *Metal Market Rev.*, 1952, vol. 4, Jan. 28, pp. 14-17.

In the course of this story of the foundation, development and present activities of the Calcutta Mint, the place of alloys in minting is considered. It is pointed out that gold has practically disappeared from the scene, and that even silver has given way to metals such as copper, nickel, and their alloys. The factors dictating choice of alloys used for coinage are listed (availability and cost of raw materials, ease of processing, wearing properties, appearance and resistance to discolouration, security against counterfeiture).

Metals and alloys at present used for the various denominations of India coinage are:—

One rupee, half rupee and quarter rupee	Pure nickel
Two anna, one anna and half anna	Cupro-nickel (75-25)
Single pice	Bronze (copper 97½, zinc 2½, tin ½, per cent.)

Nickel-Clad Steel Equipment in Production of Pliofilm

'Manufacture of 'Pliofilm'.' *International Chemical Engineering and Process Industries*, 1952, vol. 33, Jan., p. 32.

Pliofilm, introduced on the American market about 1934, is plasticized and stabilized transparent rubber hydrochloride: it was at first used mainly for raincoats and capes, but is now employed largely as a packaging material. It is impervious to humidity and moisture, and of high strength and durability.

This article gives an account of the process of manufacture used in production of Pliofilm at the works of Messrs. Goodyear Tyre and Rubber Company, Wolverhampton. The rubber hydrochloride, formed by reaction of a rubber 'cement' mixture with hydrochloric acid gas, is neutralized, heated and compounded in a nickel-clad steel tank, after which it is filtered and passed to storage tanks, from which it is fed, as required, to the 'casting unit', for conversion into film. The various stages involved in the forming operation, inspection tests on the finished product, and average properties obtained in it are described.

ELECTRODEPOSITION AND OTHER COATING METHODS

Smoothing Treatment for Steel Prior to Electrodeposition of Nickel

W. A. MARSHALL: 'A Non-Electrolytic Smoothing Treatment for Steel.' *Jnl. Electrodepositors' Tech. Soc.*, 1952, vol. 28, pp. 27-46.

Paper presented to Institute of Metal Finishing, Feb. 18, 1952.

In the course of work in the Armament Research Establishment, Woolwich, it was observed that solutions containing oxalic acid, hydrogen peroxide and sulphuric acid exert a markedly smoothing action on steels and cast iron, amounting, in the case of low-carbon steels, to a considerable degree of polish. Steels smoothed by treatment in such solutions were found to be in a condition especially suitable for plating with nickel.

The first part of the present paper describes work done to investigate the conditions under which the smoothing action takes place, and reports results of some preliminary quantitative determinations of the type and degree of smoothing achieved. The process is the subject of patent application. The second part of the paper deals with qualitative and quantitative investigations of the adhesion obtained between the smoothed steel and coatings of nickel electrodeposited on it. Qualitative experiments indicated very strong adhesion to mild steel, and in quantitative tests typical values were of the order of 50 tons per sq. in. on a low-alloy steel base.

Tests made with various solutions showed the following to be most suitable:—

	g./100 ml.
Oxalic acid (crystals)	2·5
Hydrogen peroxide	1·3
Sulphuric acid	0·01

Stronger solutions having a similar ratio of constituents may be used, but are apt to cause local furrowing of the steel surface, due to convection currents caused by the greater activity of the solutions. Using the standard solution described, rate of attack on mild steel is of the order of $0{\cdot}4 \times 10^{-3}$ in. per hour. Agitation, rise of temperature, and increased concentration cause higher rates of attack. On low-alloy steels of nickel-chromium-molybdenum types, and on grey cast iron, smoothing occurs, and with the steels there is some brightening, but the polish is not so high as that produced on low-carbon steel or malleable cast iron.

The surface of steels treated by this method is covered with a thin protective film which markedly inhibits rusting upon exposure and permits some delay between preparatory smoothing and plating. The film appears to dissolve rapidly on immersion of the steel in nickel-plating baths of low pH (e.g., 3·0), but with less acid nickel solutions (e.g., pH 5·5) removal of the film is less rapid. Commencement of deposition before the film has been totally removed may result in very low adhesion values. With alloy steels and grey cast irons smut which results from attack by the smoothing solution must be removed, prior to plating, in order to obtain maximum adhesion.

Distribution of Current and of Metal in Electrodeposition

J. KRONSBEIN: 'Current and Metal Distribution in Electrodeposition. II. Theoretical Considerations.' *Plating*, 1952, vol. 39, Feb., pp. 165-70.

Report issued under the aegis of A.E.S. Research Project No. 11. (First report, *ibid.*, 1950, vol. 37, Aug., pp. 851-4; *Nickel Bulletin*, 1950, vol. 23, No. 10, p. 177).

The aim of this research is to elucidate and summarize some underlying quantitative principles essential to a fuller understanding of the subject.

The report is classified in four main sections, relating, respectively, to Ohm's law; equipotentials and current lines, or surfaces; geometrical arrangement of electrodes with uniform current distribution; cases of non-uniform current distribution on the cathode. A later report in the series will make specific recommendations for regulating distribution of current.

Influence of Ultrasonics on Electrodeposition of Nickel

A. ROLL: 'The Influence of Ultrasonics on Electrolytic Processes. V. Effect on the Properties of Electrodeposited Metals.' *Zeitsch. für Metallkunde*, 1951, vol. 42, Sept., pp. 271-3.

Earlier work in this series of investigations was reported *ibid.*, 1950, vol. 41, pp. 339-43; 1951, vol. 42, pp. 238-43; *Nickel Bulletin*, 1951, vol. 24, Nos. 5 and 12, pp. 99 and 230. This later instalment reports observations made on the nature of the surface, the structure, and the microhardness of nickel electrodeposited under the influence of ultrasonic irradiation. It was found that types of surface characteristic of a certain range of current density occurred at higher current densities when ultrasonic waves were applied: this effect varied with the intensity of the ultrasonic energy. When the ultrasonic waves were sufficiently strong to cause cavitation, the surface showed definite signs of injury: this effect was at a maximum when the waves impinged perpendicularly to the surface of the cathode. Crystal structure was affected by ultrasonic waves in a manner similar to that produced by mechanical agitation of the bath. Microhardness was not affected by such treatment.

Casting of Anodes for Electrodeposition of Nickel

See abstract on p. 95.

Nickel-Plating of High-Tensile Steels

H. CANN and V. F. HENLEY: 'Plating High-Tensile Steels. Some Notes on Methods of Pre-Treatment and Electrodeposition.' *Aircraft Production*, 1952, vol. 14, Mar., pp. 87-8.

It is pointed out that production of satisfactory electrodeposits on steels having an ultimate tensile

strength of over 65 tons per sq. in. necessitates a careful selection of processes, in order to secure good adhesion and to ensure minimum interference with the mechanical properties of the basis steel. The primary importance of correct preparatory cleaning methods is urged and recommendations are made with regard to mechanical and chemical processes for scale-removal, and baths and procedure for etching. The types of bath used for nickel- (standard Watts type), chromium-, brass-, cadmium- and zinc-plating are indicated, and a note is added on the desirability of a post-plating low-temperature heat-treatment for removal of occluded hydrogen.

Plating of Stainless Steel

AMER. SOC. TESTING MATERIALS: 'Tentative Recommended Practice for Preparation of and Electroplating on Stainless Steel.' *A.S.T.M. B.*254-51*T.*
1951 Supplement to Book of A.S.T.M. Standards, Part 2, pp. 297-304.

Accepted by the Society June, 1951; for abstract see *Nickel Bulletin*, 1951, vol. 24, No. 7, p. 149.

Nickel Plating of Aluminium Alloys

AMER. SOC. TESTING MATERIALS: 'Tentative Recommended Practice for Preparation of and Electroplating on Aluminum Alloys.' *A.S.T.M. Designation B.*253-51*T.*
1951 Supplement to Book of A.S.T.M. Standards, Part 2, pp. 287-96.

Accepted by the Society, June, 1951; for abstract see *Nickel Bulletin*, 1951, vol. 24, No. 7, p. 149.

Electrodeposition of Nickel on Aluminium, Using Synthetic Underlay

'Protection of Aluminium by Nickel Plate over Synthetic Base Resists Corrosion and Erosion.' *Precision Metal Molding*, 1951, vol. 9, Dec., p. 49.

Note on new type of coating developed by Bart Laboratories Co., Inc., in response to the requirements of the aircraft industry. It is claimed that the 'Alni-Clad' process gives a hard, stress-free and erosion-resistant surface.

The aluminium base is prepared for plating by spraying the synthetic material (the nature of which is not stated) onto the surface, to a thickness of about 0·003 in. The work is then put through a drying cycle and subsequently electroplated with nickel, to a thickness of 0·010 in. or more, according to requirements. It is claimed that the bond between the synthetic coating and the nickel is excellent and that it is not impaired by exposure to temperatures in the range −50° to 200°F. (−46° to 93°C.). Adhesion tests have indicated the tensile strength of the bond to be of the order of 1200 p.s.i. The finished surface has a Vickers hardness of 400-450. The new coatings are of particular interest to the aircraft industry in view of their ability to resist corrosion from salt spray or alkaline corrosives, and their immunity from injury by flying grit or sand. It is suggested that the general industrial applications of the process may be extensive.

Corrosion-Resistance of Copper-Nickel-Chromium Plated Diecastings: Accelerated and Atmospheric-Exposure Tests

M. R. CALDWELL, L. B. SPERRY, L. M. MORSE and H. K. DELONG: 'Corrosion Resistance of Copper-Nickel-Chromium Plated Zinc-, Aluminum- and Magnesium-base Diecastings.' *Plating*, 1952, vol. 39, Feb., pp. 142-8, 159-63.

The paper reports, in much detail, results of co-operative investigation carried out to determine the rate and type of corrosion undergone by plated diecastings in various types of atmosphere; the thickness of coating required to give adequate protection; the influence of the type of aluminium-alloy base on which the coatings are deposited, and the comparative behaviour of Watts-nickel and bright-nickel coatings.

The types of base material used are shown below:—

Zinc-base alloy ..	containing: aluminium 3·5-4·3, copper 0·10, magnesium 0·03-0·08, per cent.
Magnesium-base alloy	containing: aluminium 9·0, manganese 0·2, zinc 0·6, per cent.
Aluminium-base alloys	containing— (1) copper 3·0-4·0, silicon 4·5-5·5, per cent. (2) copper 3·0-4·0, silicon 7·5-9·5, per cent. (3) magnesium 7·5-8·5 per cent.

Specimens were prepared with copper undercoats ranging from 0·0003 to 0·0005 in., and the superimposed nickel coatings varied from 0·0003 to 0·0015 in. in thickness. Both Watts-type and bright nickel coatings were used. In all cases the final chromium layer was 0·00001 in.

The plated panels were tested: (1) by exposure to salt-spray, (2) by exposure to four representative types of atmosphere, for a period of twelve months. The system of rating used in examination provided for recognition of three main defects: (1) corrosion or staining of the plating, (2) corrosion of the base metal, and (3) blistering of the plating. Typical photographs show the condition of the panels after the various tests, and graphs illustrate effect of thickness of plating, time of exposure, correlation between salt-spray and atmospheric-exposure ratings, etc. The conclusions drawn from the tests are summarized below:—

To provide adequate protection against corrosion of zinc-, aluminium- or magnesium-base diecastings for one year, a total plate-thickness of 0·002 in. (51μ) was necessary.

On zinc-base castings the protection given by the plating was proportional to its thickness, but additional protection gained by depositing more than 0·00125 in. (32μ) was comparatively small.

In general, protection of the aluminium or magnesium alloys afforded over the one-year period by a 0·00125 in. (32μ) coating was very inadequate, but the degree of protection was much increased by an additional 0·00075 in. (19μ) of coating.

Corrosion of the plated aluminium-alloy specimens, once any break in the coating had occurred, progressed along the interface of the plate and the base metal.

No. 2 type of aluminium alloy was slightly better

as a base metal than alloy 1; alloy 3 rated as a poor third. Corrosion of the plated magnesium alloy progressed into the basis metal, forming craters of increasing size, which gave off voluminous grey corrosion products.

In a heavily industrial atmosphere buffed Watts nickel over the zinc alloy was poorer than unbuffed bright nickel, whereas in a marine atmosphere it behaved better. Averages of ratings for all locations indicated that the buffed Watts nickel was slightly better in overall behaviour.

Over aluminium alloy No. 1, in coatings of total thickness 0·0008 in. (20μ), buffed Watts nickel was slightly, but definitely, better than buffed bright nickel, in all locations.

For the magnesium alloy with a total plating thickness of 0·00125 in. (32μ) buffed Watts nickel was slightly, but definitely, better, in all locations than buffed bright nickel. On aluminium- and magnesium-base alloys buffing of the bright-nickel plating had practically no effect on corrosion-resistance.

Corrosion of zinc-base die-castings is less objectionable than that of the other alloys tested, in that the corrosion products can be easily polished off, whereas with plated aluminium alloys large blisters are formed, which cannot be so removed, and on plated magnesium-base materials fewer, but larger, pits are formed.

In general, very little correlation was found between salt-spray-test results and either exposure-test data or thickness of coating.

Accelerated Corrosion Testing of Nickel-Chromium Coatings

H. HEFELE: 'Contribution to the Study of the Accelerated Corrosion Testing of Electrodeposited Chromium-Nickel Coatings.' *Metalloberfläche*, 1952, vol. 4, Feb., pp. B 17-24.

As an introduction to a consideration of test methods, the author briefly reviews the characteristic features of the three main types of defect occurring in electrodeposited coatings: (1) porosity and blistering, (2) cracking, (3) peeling of the coating. Typical examples of each form of defect are shown.

The accelerated tests which have been proposed for determining susceptibility to porosity and corrosion are then considered: salt-spray test; storage in humid conditions; measurement of thickness of electrodeposited coating; porosity testing by boiling water or ferroxyl test. An extensive review is made of results which have been obtained by various investigators who have used the ferroxyl test; details of the solutions used, mode of application, etc., are tabulated, and reference is given to sources of the original work. The views of other investigators on the usefulness of the test are correlated with the author's own results, obtained in testing by means of a specially severe form of ferroxyl procedure. The results of these tests showed no correlation with behaviour of coatings under atmospheric exposure, and it is urged that a critical investigation should be carried out to determine composition of solution and conditions of test giving closest approximation to behaviour under natural weathering conditions. The last section of the review is concerned with the information obtainable by the use of a hydrochloric-acid spray test, which, on certain types of coating, is considered to give results more closely indicative of probable behaviour under atmospheric conditions. The author is of the opinion, however, that the present stage of development and knowledge on porosity testing of electrodeposited coatings is far from satisfactory, and that further investigation is essential, in order to evolve methods by which it is possible to obtain consistent and unequivocal indication of the durability of metallic coatings under service conditions.

Inspection Testing of Electroplated Parts for Aircraft

P. SKEGGS: 'Inspection of Electroplated Aircraft Parts.' *Jnl. Electrodepositors' Tech. Soc.*, 1952, vol. 28, pp. 15-26.

Paper presented to Institute of Metal Finishing, Nov. 19, 1951.

A review is made of inspectional requirements laid down in D.T.D. specifications covering plating of aircraft parts. Individual sections of the paper relate to the methods used in sampling, pre-plating inspection, thickness testing, porosity testing. Details are also given of specification requirements laid down for particular types of coating:—hard chromium plating; nickel and silver plating on aluminium, steel and copper; rhodium plating; and surface treatment of zinc and cadmium.

Electroformed Nickel in Microwave 'Plumbing'

V. J. MARCHESE: 'Stress Reduction of Electrodeposited Nickel.' *Jnl. Electrochemical Soc.*, 1952, vol. 99, Feb., pp. 39-43.

The majority of electroforming operations for microwave 'plumbing' involve electrodeposition of copper, and this metal has proved satisfactory in fabricating precision microwave tubing and various odd-shaped objects used in the microwave field, such as re-entrant cavities and rectangular and round adaptors. The electrodeposition of iron is used primarily in wavemeter cavities, on account of its favourable coefficient of thermal expansion.

Electroformed nickel, if deposited with low internal stress, offers some advantages over copper or iron, due to its superior physical and corrosion-resisting properties. It has, for example, greater rigidity, and electroformed nickel microwave equipment could therefore be made with a thinner wall (approximately 0·020 in.) and still be mechanically satisfactory. Also, the resultant wave guide would be almost as light in weight as one fabricated from aluminium.

Electrodeposited nickel, however, as obtained from many of the baths at present in use, e.g., the Watts solution, is characterized by a degree of internal stress sufficient to prevent removal of electroformed nickel from non-destructible mandrels such as steel, stainless steel, or Invar. Moreover, when destructible mandrels, zinc, low-melting-point alloys, or plastics are used, the electroformed nickel object distorts considerably upon removal of the mandrel. This paper describes a method of electrodeposition designed to

overcome this difficulty, by depositing a nickel containing only a very low level of stress.

After a short survey of earlier work on electrodeposition of stress-free nickel, the author reports (1) experiments made with a standard Watts bath containing additions of saccharin, and (2) tests on stress reduction by means of superimposing alternating current on direct current. The results showed that although stress could be made compressive by adding saccharin in excess of the amounts required to reduce the stress to zero, this method gives erratic results, and control of such solutions, under commercial operating conditions, would not be practical. Superimposing alternating current on direct current reduced the stress in nickel deposited from a Watts bath: minimum stress of 2,500 p.s.i. was obtained when 60-cycle alternating current was superimposed on direct current at a ratio of a.c. peak voltage to d.c. voltage of three to one and at a bath pH of 4·5. Experience with actual electroforming of nickel by this latter means is at present very limited, but experiments reported in the paper relating to electroformed nickel on Invar gave promising results, and it is considered that the process is a feasible one.

Direct Enamelling of Steel: Influence of Nickel Dip

G. S. DOUGLAS and J. M. ZANDER: 'X-Ray Study of the Reactions at the Steel Surface when Titania Enamel is Applied Directly.' *Jnl. Amer. Ceramic Soc.*, 1952, vol. 35, Jan. 1, pp. 5-11.

The problem of applying cover-coat enamels directly to steel has received fresh impetus from the development of titania enamels and titanium-bearing steel to which they can be applied with some measure of success. In view of the potential importance of the method (already in use by some producers of enamelled ware) it was considered desirable to make a detailed study of the phenomena involved. Investigation was therefore carried out to ascertain the nature of the reactions occurring during the enamelling cycle, and how such reactions are affected by variables such as firing temperature and type of steel, and the possible relationships between such reactions and adherence.

Two different types of steel were used in the experiments: (1) a titanium-bearing steel (Ti-Namel) and (2) a regular enamelling iron manufactured by Armco Steel Corporation. Sheets of each steel (20-gauge) were cut into 5 × 8-in. plates and were pickled in a batch-production unit in accordance with standard pickling practice. Some of the specimens were prepared without a nickel flash; others were immersed for various periods in a nickel-pickling bath, to secure varying weights of nickel deposit. The weights of nickel coating were determined by the titration method described by ZANDER (*Better Enameling*, 1945, vol. 16, No. 1, pp. 8-9).

The enamel used was a commercial titania-opacified cover coat, designed for firing at about 1470°F. (800°C.) over ground coat. Full details of preparation of the specimens, application of the enamel, firing conditions, etc., are given.

X-ray studies showed the following crystalline compounds near the interface, under various conditions: (1) Fe_3O_4; (2) FeO; (3) $FeTiO_3$; (4) anastase; (5) rutile; (6) nickel-iron alloy, and (7) an unidentified compound designated 'unknown X'.

The Fe_3O_4 and FeO make up the initial oxide layer which forms on the steel before the enamel fuses. The $FeTiO_3$ is formed by reaction between dissolving FeO and dissolved TiO_2 in the enamel. Anastase is the primary opacifying crystal which precipitates because of supersaturation of the frit, but it is drawn back into solution as $FeTiO_3$ precipitates. Rutile is a secondary opacifier which forms relatively slowly and apparently causes the re-solution of the $FeTiO_3$. The nickel-iron alloy appears only as a trace and probably comes from reaction between FeO and a small amount of nickel oxide formed on the nickel-flashed samples.

The most important observable effect of nickel pickling is its drastic reduction of the amount of oxide initially formed. Increasing the firing temperature increases the rate of all the reactions, but most particularly the precipitation of rutile and the disappearance of $FeTiO_3$. Development of adherence of the enamel used, on Ti-Namel steel, is dependent to a great extent on the weight of nickel deposit and the firing temperature and time. The theory that adherence depends on the presence of an oxidizing agent in the enamel adjacent to the steel was applied to this system, and correlation was observed, on the assumption that dissolved TiO_2 is the adherence-promoting agent. The titania enamel does not develop adherence on a regular enamelling iron under conditions in which good adherence is developed by it on Ti-Namel steel, although the reactions observed in the enamel are essentially the same in both cases. This difference, it is considered, may result from differences observed in crystal orientation or texture, behaviour of the nickel deposit, or effects of hydrogen.

Determination of Magnesium in Nickel-Plating Solutions

K. E. LANGFORD: 'A Rapid Method for the Determination of Magnesium in Nickel Plating Solutions, Using Disodium Ethylene Diamine Tetra-Acetate.' *Electroplating*, 1952, vol. 5, Feb., pp. 41-6.

The author reports that he has for some time used the method described, for boiler-water control: he gives full details of its application for estimation of the larger amounts of magnesium present in nickel-plating solutions in which magnesium-sulphate additions are made to increase conductivity, for improvement of throwing power, etc. It is urged that magnesium-containing solutions are very satisfactory for general-purpose plating, but that their use is not yet fully appreciated, due in part to difficulty of analytical control.

In the method described magnesium is titrated with disodium ethylenediamine tetra-acetate, using Erichrome Black T (Solochrome Black WDFA) as indicator, in presence of ammonium chloride, ammonium hydroxide and sodium cyanide. For concentrations of $MgSO_4$ exceeding 8-10 g./L. (about 1½ oz./gal.) accuracy of results by the new method may exceed that given by the normal time-consuming gravimetric procedure. For lower concentration, using a more dilute titrant, the accuracy may be slightly inferior

to that of the gravimetric procedure, but it is adequate for normal control purposes. Aluminium, trivalent chromium, and manganese interfere, but are seldom present in normal nickel-plating solutions.

Analytical procedure is detailed below:—

'Pipette 5 ml. of the nickel solution into a 400-ml. Phillips beaker; dilute to 50 ml. with water and add 2-3 g. of ammonium chloride, followed by sufficient sodium cyanide to re-dissolve the precipitate of nickel cyanide first produced (approx. 4 g.). Add 5 ml. concentrated ammonia, followed by 6-8 spots of indicator. Titrate with *N*/5 E.D.T.A. solution until the colour of the solution changes from a pinkish-red tint to a blue-violet. Time: 5 minutes.

1 ml. *N*/5 E.D.T.A. = 0·02463 g. $MgSO_4.7H_2O$

'*Preparation of the N/5 E.D.T.A. Solution*

Dissolve 38 g. powdered disodium ethylenediamine tetra-acetate in water and make up to 1 litre. Standardize against Analar magnesium sulphate, $MgSO_4.7H_2O$, taking sufficient of the salt to give a burette reading of approximately 20 ml. The titration is carried out by adding 2 g. ammonium chloride and 5 ml. ammonia to the solution. 4-6 spots of indicator are used.

'*Preparation of Indicator*

0·5 g. Erichrome Black T (Solochrome Black WDFA, by I.C.I., Ltd.) and 4·5 g. hydroxylamine hydrochloride are dissolved in 100 ml. alcohol or industrial spirit.'

Both the E.D.T.A. reagent and the indicator are stated to be very stable.

NON-FERROUS ALLOYS

Magnetic Investigation of Sintering in a Nickel-Copper Alloy

W. KÖSTER and J. RAFFELSIEPER: 'Magnetic Study of Diffusion on Sintering of a Nickel-Copper Alloy.' *Zeitsch. für Metallkunde*, 1951, vol. 42, Dec., pp. 387-91.

Report of work on an alloy containing nickel 89, copper 11, per cent., prepared from carbonyl-nickel and electrolytic-copper powders. The compacts were heated, in purified hydrogen, for periods varying from one to sixty-five hours at temperatures of 800°, 900°, 950°, 1000°, 1050° and 1100°C., and for periods varying up to twenty-five hours at 1200°C. Curves of composition *vs.* heating time and temperature were obtained on alloys so treated, by means of measurements of the magnetization-saturation values of the alloys, as a function of temperature. The magnetic measuring equipment used was of the type developed by Gerlach: its main features are described in the introduction to the report. Nickel-copper was chosen as being specially suitable for a fundamental investigation of the kinetics of the sintering process, since nickel and copper form a continuous series of solid solutions, and alloys of this system containing up to 34 per cent. copper are ferromagnetic.

Equipment for Thermal Treatment: Institute of Metals Symposium

See abstract on p. 93.

Lithium Treatment for Degassing of Nickel-containing Alloys

'Degassing with Lithium.' *Metal Industry*, 1952, vol. 80, Mar. 7, pp. 191-2.

The article reports experiments made on the effect of addition of lithium (0·002-0·01 per cent.) to Monel, nickel bronze, leaded bronze and nickel silver. It was found that the best average addition was 0·005 per cent., added immediately before casting, and after deoxidation with 0·08 per cent. magnesium.

Addition of lithium to Monel proved to have a definitely degassing effect, and also tended to disperse the film of magnesium liable to form on the surface of the melt. Tensile strength and elongation of lithium-treated castings were found to be higher than those of castings which had not been so treated, and the structure showed marked grain refinement.

In nickel-bronze alloys additions of 0·005-0·01 per cent. of lithium assisted degasification and very effectively cleansed the metal, making it more 'alive'. The effect of the treatment on tensile properties and grain-size was not determined in this case.

In leaded-bronze alloys, which had been prone to pinhole porosity, an addition of 0·007 per cent. of lithium, following the normal addition of 0·04 per cent. phosphorus, produced melts completely free from gas, and the improvement was confirmed by subjecting the castings to accepted criteria for assessment of soundness in castings.

For nickel silver use of lithium, 0·008-0·01 per cent., in place of magnesium, is recommended as giving increased cleanliness, producing castings of better surface finish and improving pressure tightness. In this alloy, as in Monel, the lithium-treated metal shrank in the runners and feeding heads more than lithium-free metal, further proving the effectiveness of this addition as a degassing agent.

It is noted that the work reported was carried out *ad hoc*, to meet contingencies arising in production, and is reported as practical experience, not as the results of research. No attempt has yet been made to elucidate the mechanism of the effect of lithium on the liquid metals, but it is hoped to investigate the matter more fundamentally at a later stage.

Hysteresis of K Monel and Inconel in Torsion

W. P. WELCH and B. CAMETTI: 'Hysteresis of Shaft Materials in Torsion.' *Amer. Soc. Mechanical Engineers, Paper* 51-*A*-64, Aug., 1951; 11 pp.

The term 'elastic hysteresis' is now the generally accepted term for describing inelastic effects at stresses below the conventional elastic limit. In the design of torque-weighing devices an important practical problem is the selection of a shaft material having very low hysteresis and creep, and the tests reported in this paper were carried out in this connexion. Since the application of particular interest to the authors involved shafts of large diameter, the tests were confined to materials which could be supplied in large-size shafting, and the specimens were solid, as being representative of shafting used in the service envisaged. One tubular specimen was included for comparison.

The materials tested were S.A.E. 4140 chromium-

molybdenum steel, S.A.E. 1015 carbon steel, K Monel, and Inconel X: the last two alloys were included on account of their non-magnetic properties. Heat-treatments chosen for the respective materials were typical of those producing the best properties attainable in shafting of large diameter.

Among the conclusions drawn from the tests are the following: In chromium-molybdenum steels for stresses up to 24,000 p.s.i. (10·75 tons per sq. in.) hysteresis and creep are low, 0·03 per cent. for unidirectional loading. For reversed bending, however, the hysteresis is many times greater, sufficiently large to be objectionable in torque-measuring systems.

The hysteresis values in torsion for a thin-walled tubular specimen proved to be large compared with those for solid specimens of similar material.

Low-carbon steel, as was anticipated, showed large hysteresis in all the test conditions imposed. For both the plain and the chromium-molybdenum steels, strain history had an important influence on behaviour. The non-magnetic alloys, K Monel and Inconel X, proved to have exceptionally low hysteresis and creep for shearing stresses up to 24,000 p.s.i. (10·75 tons per sq. in.). Both hysteresis and creep values were only 0·01 per cent., even for reversed loading.

Copper-Nickel Alloy Castings

J. S. VANICK: 'Cupro-Nickel Castings.' *Foundry*, 1952, vol. 80, Feb., pp. 100-5, 246-8, 250-3.

This review is a further item in the series on copper-base alloys containing nickel which have been contributed recently to *Foundry*. Compositions typical of 70-30, 80-20 and 90-10 grades are tabulated, together with details of U.S. Navy specification 4608a which covers the 70-30 grade. Impurity maxima in these alloys are stated to be of the following order:—lead 0·05, aluminium 0·05, zinc 1·0, tin 1·0, carbon 0·15, sulphur 0·02, per cent. Current U.S. Navy specifications permit higher aluminium contents, and also the use of titanium additions.

Practical information on the production, processing and uses of cast copper-nickel alloys is given in this article under the following headings:—

Foundry Practice. Broadly speaking, this follows copper-melting practice. Contact with sulphur, hydrogen and carbon is to be avoided. Oxidation is effected by addition of nickel oxide or copper oxide, and deoxidation is done by a three-step process, employing additions of manganese, silicon and magnesium.

Composition and Properties. Certain impurities may be helpful in limited amounts, e.g., carbon, aluminium and tin: others, such as lead, zinc and sulphur, must be rigidly excluded. Effects of the respective impurities and the limits which must be placed on them are discussed. Among the desirable alloying elements, iron, silicon, manganese and carbon are rated as essential, while aluminium, tin and some other elements are employed for specific purposes. The modifications produced by such additions are illustrated, and tables list typical cast cupro-nickels containing (1) tin, (2) silicon+tin, (3) aluminium. Some of the uses of the various alloys are described, with photographs. The data demonstrate the useful range of properties available in the straight and modified cast alloys of copper-nickel base.

Attention is directed to the high corrosion-resistance characteristic of cupro-nickel alloys and to their widespread application in handling fresh and salt waters. It is also shown that the cupro-nickels retain a useful combination of properties at moderately elevated temperatures, rendering them suitable, for example, for various applications in steam plant. Retention of a good degree of toughness at sub-normal temperatures indicates their suitability for refrigerator parts and other components used in low-temperature applications: for this type of service the absence of tin is desirable. The electrical-resistance characteristics of the copper-nickel alloys are briefly reviewed, indicating the value of the materials for various electrical-engineering applications.

Welding, Brazing and Soldering operations can be successfully performed on cupro-nickel castings specifically made for such purpose: precautions desirable with regard to composition and purity, preparation, etc., are noted.

Uses. The final section of the review contains a list of some typical uses of cupro-nickel alloys, of simple and complex types, based on the range of properties which can be developed in them by suitable adjustment of composition, alloying, and heat-treatment.

Welding, Brazing and Soldering of Copper and Copper Alloys

COPPER DEVELOPMENT ASSOCN.: 'The Welding, Brazing and Soldering of Copper and its Alloys.' *C.D.A. Publn.* 47, 1951; 188 pp.

This publication gives a comprehensive review of the subject. It is introduced by a chapter on basic principles of metallurgy affecting welding, and a consideration of the physical and chemical properties of copper and its alloys. This is followed by a discussion of the nature of welding processes (oxy-acetylene, arc, and resistance), which leads to chapters dealing with the various methods of joining the respective coppers and copper-base alloys. Mechanical test results on joints are given in many cases, to illustrate the nature of the welds which may be obtained by the various methods.

Throughout the book references are given to relevant B.S. specifications, and there is a comprehensive *bibliography* of papers published in English on the respective aspects of the subject.

In addition to the information given on welding of copper and its alloys, their use in joining of cast iron, steel and other materials is discussed.

The section relating to copper-nickel and related alloys covers nickel bronzes, nickel silvers or nickel brasses, and cupro-nickel alloys containing 5-45 per cent. nickel.

Specification for Nickel Silver Strip and Foil

BRIT. STANDARDS INSTN.: 'Nickel Silver Strip and Foil for the Telecommunication Industries.' *B.S.* 1824: 1952.

Covers wrought nickel silver in the form of strip up to and including 0·128 in. (3·25 mm.) thick, and foil in widths not greater than 12 in. (30·5 cm.).

Two ranges of composition are included, from which final selection may be made by the purchaser:—

	Nickel (incl. Cobalt)	Copper	Zinc	Manganese
(1)	% 17-19	% 54-56	% 25-29	% 0·35 max.

with the following limit to impurities: lead not more than 0·03, sulphur not more than 0·03, total impurities (including lead and sulphur) not more than 0·35, per cent.

	Nickel (incl. Cobalt)	Copper	Zinc	Manganese
(2)	% 11-13	% 60-65	% 22-29	% 0·35 max.

Limits for impurities as in (1).

The specification includes tables of tolerances on width, length and thickness, details of temper grades, and requirements for hardness and bend testing.

Nickel Silver Alloys in the Watch Industry

'Copper Alloys in the Watch Industry.' *Metal Industry*, 1952, vol. 80, Feb. 15, pp. 127-30.

The article is an abridged translation of information published in *Pro-Metal:* it is based on practice in the Swiss watchmaking industry. Compositions and physical properties are tabulated for the main brasses and nickel silver alloys commonly employed, and the uses of the respective grades are discussed. Frames, escapements and cases are individually dealt with.

Properties of 12 per cent. Nickel Silver for Springs

G. R. GOHN: 'Conservation of Nickel.' *A.S.T.M. Bull.*, 1952, No. 179, Jan., p. 32.

A.S.T.M. Committee B-5 (Copper and Copper Alloys) draws attention to conservation of nickel which may be effected by using a 12 per cent. nickel silver in place of the 18 per cent. alloy for small flat springs. This proposal was first made during the last war, and in 1946 A.S.T.M. Specification B 122 was revised to include the 12 per cent. nickel grade. This alloy has a nominal composition of copper 56·5, nickel 12, zinc 31·5, per cent. Tensile strength and hardness data for the alloy are given in Table I (in comparison with the properties of 18 per cent. nickel silver), and Table II contains additional data of particular interest in connexion with use of the alloy for springs and other engineering purposes. The information given is based on determinations made in Bell Telephone Laboratories, Inc.

Table I

Tensile Strength Requirements of Rolled Plate, Sheet and Strip in Copper-Nickel-Zinc Alloys

Temper	Tensile Strength, p.s.i.		Rockwell Hardness* (Values included as Information Only)					
			G Scale		B Scale		Superficial 30-T	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
ALLOY NO. 4 (55 CU, 18 NI, 27 ZN)								
Quarter hard	69,000	87,000	23	62	70	88	63	75
Half hard	78,000	95,000	51	69	81	92	71	78
Hard	92,000	107,000	67	76	90	96	76	80
Extra hard	102,000	115,000	73	80	95	99	79	82
Spring	108,000	120,000	77	83	97	100	80	—
ALLOY NO. 8 (56·5 CU, 12 NI, 31·5 ZN)								
Quarter hard	65,000	81,000	—	—	61	85	57	74
Half hard	75,000	91,000	—	—	78	91	69	77
Hard	90,000	105,000	—	—	90	95	76	79
Extra hard	101,000	114,000	—	—	94	98	79	81
Spring	109,000	122,000	—	—	97	100	80	—

* Rockwell hardness values are given in this table only as information and are significant to the nearest number. They apply as follows to rolled plate, sheet and strip: The B and G scale hardness values apply to metal 0·020 in. and over in thickness, and the 30-T scale hardness values apply to metal 0·012 in. and over in thickness.

Table II

Mechanical Properties of Two Copper-Nickel-Zinc Alloy (Nickel Silver) Spring Materials (Strip)
(Stress Values in p.s.i.)

Material	Temper	Grain, Direction, deg.	Rockwell Hardness	Proportional Limit	Yield Strengths, per cent.			Fatigue Limit at 10^8 Cycles of Reversed Stress	Tensile Strength	Elongation per cent. in 2 in.	Young's Modulus
					0·01 Set	0·2 Set	0·5 Elong.				
Alloy No. 4 Nickel Silver Strip per A.S.T.M. B 122-50T (18 per cent. Ni)	(Soft)	0	B 49	—	19,200	26,000	26,800	16,000	62,900	45·0	$19·6 \times 10^6$
		45	B 49	17,500	21,700	25,800	26,400	—	61,700	47·0	19·4
		90	B 49	17,500	22,400	26,100	27,200	—	62,200	47·0	20·7
	(Hard)	0	B 92	43,600	63,700	100,400	89,100	21,500	101,500	1·0	20·4
		45	B 92	41,800	59,000	88,600	76,700	—	97,600	2·5	17·6
		90	B 92	48,300	60,700	92,200	83,700	—	101,400	2·3	20·6
	(Extra Hard)	0	B 93	42,900	60,200	100,200	90,800	21,000	104,800	1·5	21·2
		45	B 93	44,700	58,000	89,900	78,000	—	98,300	2·2	18·1
	(Spring)	0	B 98	47,300	68,000	—	94,900	23,500	110,300	1·5	21·5
		45	B 98	48,600	65,900	100,400	83,700	—	109,200	2·0	18·8
		90	B 98	57,800	71,400	107,300	93,300	—	115,600	2·0	21·5
Alloy No. 8 Nickel Silver Strip per A.S.T.M. B 122-50T (12 per cent. Ni)	(Soft)	0	B 46	16,600	19,900	—	—	—	62,400	59	16·3
		45	B 46	17,800	21,500	—	—	—	60,800	65	16·5
		90	B 46	17,800	22,300	—	—	—	60,200	62	18·1
	(¼ Hard)	0	B 74	33,200	42,300	57,400	56,900	—	70,200	26·8	18·2
		45	B 73	29,400	35,200	49,800	49,900	—	65,100	34·3	17·2
		90	B 72	29,300	34,700	50,900	51,100	—	66,500	32·7	18·3
	(Hard)	0	B 91	36,300	56,000	—	—	—	96,100	3·2	19·6
		45	B 91	46,200	54,500	—	—	—	90,200	6·2	15·9
		90	B 91	46,900	57,400	—	—	—	93,000	5·4	18·9
	(Extra Hard)	0	B 93	53,800	71,100	105,600	84,300	23,000	107,600	2·0	18·2
		45	B 92	50,100	60,200	93,000	73,900	—	102,600	3·0	16·3
		90	B 92	51,300	63,900	96,500	82,200	—	107,400	3·0	18·9
	(Spring)	0	B 96	57,100	72,400	110,400	81,300	—	113,200	2·0	18·3
		45	B 96	52,600	65,100	99,200	74,500	—	110,400	2·0	16·0
		90	B 96	55,100	68,000	102,100	82,700	—	114,900	2·3	18·2

Nickel-Chromium Equilibrium Diagram

D. S. BLOOM and N. J. GRANT: 'Chromium-Nickel Phase Diagram.' *Jnl. of Metals*, 1951, vol. 3; Nov. (*Trans. Amer. Inst. Mining and Metallurgical Engineers*), pp. 1009-14: T.P. 3155E.

Our attention has been drawn to the fact that in the abstract of the above paper, appearing in *Nickel Bulletin*, 1952, vol. 25, Jan., p. 9, the authors' statements with regard to the work of the N.P.L. investigators published in 1936-37 have been incorrectly interpreted.

The statements referring to the purity of the metals used by earlier investigators should be taken as applying to work conducted by various research workers prior to 1930, and not as referring to the material used in the N.P.L. investigation reported in 1936-37, for which the alloys were prepared from electrolytic chromium and high-grade nickel shot of quality similar to that of the metals used by BLOOM and GRANT for the work now published.

The N.P.L. investigators, moreover, did not make reference to the existence of the compound Cr_2Ni, but favoured the simple eutectiferous diagram (see *Jnl. Iron and Steel Inst.*, 1937, No. 2, pp. 193-204). They did, however, point out that 'the thermal curves of alloys containing considerable proportions of chromium exhibit small arrests on cooling at about 950°C. and on heating at about 1100°C. These arrests may be a consequence of a somewhat sharp change in the solid solubility of nickel in chromium'. BLOOM and GRANT suggest allotropy in chromium as a cause of a sharp change in solubility at 1180°C.; they do not favour the existence of an internal maximum based on the appearance of Cr_2Ni.

Beryllium-Nickel Tucking Needles in Weaving Machines

'Redesigned to Use Investment Casting: the Swasey-Sulzer Weaving Machine.' *Precision Metal Molding*, 1951, vol. 9, Dec., pp. 34-5, 61.

The article describes the features of a weaving machine which differs materially from a standard loom. Whereas in the loom the shuttle carries a bobbin, and only one shuttle is used at a time, the weaving machine uses up to 13 shuttles and carries no bobbin. The shuttle picks up the filler thread at the start of a cycle, carries it across the warp, and then drops the thread. The shuttle is then dropped onto a conveyor below the weaving level of the machine and is carried back to the starting position. The adaptation of investment casting to production of parts of the shuttle and other components of the weaving machine is described and illustrated. *Inter alia*, reference is made to a corrosion-resisting beryllium-nickel alloy used for the tucking needle which forms the selvedge of the cloth being woven. The material used for these needles must be highly resistant to corrosion, in order to avoid staining and snagging the thread, and it must also be hard and smooth, to ensure resistance to wear. Tucking needles were formerly made from forgings, but were replaced some time ago by precision-cast beryllium-copper needles. Later a beryllium-nickel needle was found to be much more serviceable, since it is completely resistant to atmospheric corrosion, and can be polished to the degree required.

Effect of Nickel on Transformations in Titanium

A. D. MCQUILLAN: 'The Effect of the Elements of the First Long Period on the $\alpha \rightleftarrows \beta$ Transformation in Titanium.' *Jnl. Inst. Metals*, 1951-52, vol. 80, Feb., pp. 363-6; *Paper* 1355.

The method in which the hydrogen pressure in equilibrium with an extremely dilute solution of hydrogen in a titanium-rich alloy is measured as a function of temperature in order to follow the phase transformations occurring in the alloy, described in a previous paper (*ibid.*, 1951, vol. 79, p.73) has been used for a systematic investigation of the effects of vanadium, chromium, manganese, nickel and cobalt on the $\alpha \rightleftarrows \beta$ transformation in titanium. The maximum amount of each addition element used was approximately 5 at.-per cent.

It was found that all these elements, when added to titanium, depress the allotropic transformation, and that, with the exception of vanadium, they are not appreciably soluble in the low-temperature (α) form of titanium. The extent of the depression of the $\beta(\alpha+\beta)$ boundary is substantially the same for equal atomic fractions of all the addition elements, except in the case of vanadium, which is slightly less effective in this respect than the others. The experimentally determined $\beta/(\alpha+\beta)$ boundaries were compared with an idealized theoretical boundary obtained from the known latent heat of transformation of pure titanium.

The experimental data were used to determine the effect of addition elements on hydrogen solubility in β-titanium. Vanadium caused the greatest change in this property: the other elements had but little effect.

Nickel and Nickel-Alloy Coinage in India

See abstract on p. 95.

NICKEL-IRON ALLOYS

Properties and Uses of Magnetic Alloys containing Nickel

K. HOSELITZ: 'Permanent Magnets.'
S. E. BUCKLEY: 'Permalloys.'

These two chapters, which formed parts 19 and 20 of 'Steels in Modern Industry', recently published by Iliffe and Sons, Ltd., give a useful résumé of the current stage of development within the respective spheres indicated. The chapter on permanent magnets demonstrates the recent progress in this field by a comparison of the properties of the early chromium, tungsten and cobalt magnet steels with those of the Alni, Alnico, Alcomax, Ticonal and other types which have been developed during the past few years. Some account is given of methods of manufacture employed

in production of the newer types of magnet, of ageing, storing and magnetizing treatments applied, and of methods of test.

In the chapter relating to Permalloy alloys the author discusses the compositions, properties and uses of nickel-iron alloys containing 35-90 per cent. nickel, with or without modifying additions of other elements such as molybdenum, chromium, copper, cobalt, etc. A classification is made of the alloys according to their magnetic characteristics: *alloys of high initial permeability*, e.g., Permalloy C, Supermalloy, 1040 alloy, and Mumetal; *alloys of constant initial permeability*, e.g., Perminvars, Isoperms, and Conpernik; *alloys of high magnetic saturation*, e.g., Permalloy B, Hipernik, Radiometal and 4750 alloy; *alloys of high resistivity*, e.g., Permalloy D. Variation of effective permeability is discussed with reference to the effect of thickness, frequency, temperature and polarization. Factors affecting choice of magnetic cores for various applications are reviewed, production of Permalloy dust cores is described, and an outline is given of performance characteristics of dust cores.

(The chapter on 'Permalloys' should be added to the contents list of the book given in *Nickel Bulletin*, 1952, vol. 25, No. 2, p. 45).

Nickel-Iron Alloys in Magnetic Modulators

E. P. FELCH, V. E. LEGG and F. G. MERRILL: 'Magnetic Modulators.' *Electronics*, 1952, vol. 25, Feb., pp. 113-17.

The paper describes in detail magnetic-amplifier devices developed by Bell Telephone Laboratories, for conversion of low-level, low-frequency or d.c. signals to a.c. signals capable of being amplified by conventional means. The instruments are called magnetic modulators or magnettors. Cores are of 4-79 molybdenum-Permalloy.

Electrical-Resistance Characteristics of a Nickel-Iron-Molybdenum Alloy

F. ASSMUS and F. PFEIFER: 'Resistance Anomalies in a High-Permeability Nickel-Iron-Molybdenum Alloy.' *Zeitsch. für Metallkunde*, 1951, vol. 42, Oct., pp. 294-9.

The material examined was of the Supermalloy type (nickel 79, molybdenum 5, per cent., balance iron), in which a condition of maximum permeability is produced by heat-treatment in a magnetic field followed by tempering at 400°-500°C. Comparative experiments were carried out on two straight nickel-iron alloys (50-50 and 67-33, per cent., respectively): measurements were made of permeability and electrical resistance as functions of tempering treatment. The increase in permeability known to be obtained in Supermalloy by tempering was found to be accompanied by an increase in room-temperature electrical-resistance values, and it was also observed that resistance at raised temperatures was affected by rate of cooling and by the length of time for which the material was held at a given temperature.

The effects observed are in contrast to phenomena known to be characteristic of nickel-iron Permalloys, indicating that the processes occurring in the molybdenum-containing alloys are either more complicated than, or different in nature from, those taking place in the binary types, in which superstructure formation may be regarded as responsible for the anomalies observed. The anomalies in electrical resistance observed in the nickel-iron-molybdenum alloys parallel closely anomalies which have been recognized in a whole series of other alloys, of which the nickel-chromium system is typical. The authors draw comparisons between the effect of heat-treatment on a 79-21 nickel-chromium alloy and on an alloy of the molybdenum-Permalloy type.

CAST IRON

Specifications for Spheroidal-Graphite Cast Iron

AMER. SOC. TESTING MATERIALS: 'Tentative Specifications for Nodular Iron Castings.' *A.S.T.M. Designation A.339-51T.*

The specification, accepted by the Society in November, 1951, covers castings made of nodular- or spheroidal-graphite (or ductile iron), defined as cast iron with the graphite substantially in spherical shape and substantially free of flake graphite. Although it is the intent of these specifications to subordinate chemical composition to mechanical properties, it is provided that the quantities of any chemical elements in the iron may be specified by agreement between manufacturer and purchaser. The mechanical-property requirements are as follows:—

	Grade	Grade
	80-60-03	60-45-10
Tensile strength, min.	80,000 p.s.i.	60,000 p.s.i.
	(36 t.s.i.)	(27 t.s.i.)
Yield Strength, min.	60,000 p.s.i.	45,000 p.s.i.
	(27 t.s.i.)	(20 t.s.i.)
Elongation in 2 in., min.	3·0%*	10%

*Where strength is the primary requirement the elongation requirement in grade 80-60-03 may be waived by agreement between manufacturer and purchaser. It is intended that the properties of the 60-45-10 grade shall be obtained by a graphitizing annealing treatment, but by agreement between manufacturer and purchaser castings are to be deemed acceptable if the properties specified are attained without heat-treatment.

Form of test coupons and of tension-test specimens is laid down.

Engineering Properties and Uses of Spheroidal-Graphite Cast Iron

M. M. HALLETT: 'Ductile Cast Iron.' *Trans. Inst. Marine Engineers*, 1952, vol. 64, Feb., pp. 25-30; disc., pp. 30-3.

Final form, with discussion, of paper abstracted in *Nickel Bulletin*, 1952, vol. 25, No. 1, pp. 13-14.

The discussion was opened by A. B. EVEREST, who

drew attention to the fact that the new irons could be made with many different matrix structures, and that wear-resistance would vary considerably from type to type. He also commented on further advances which had been made in magnesium-treated Ni-Resist irons since the date of the author's tests. Continued research had shown that when copper-free grades of Ni-Resist were treated by the magnesium process even better results could be obtained than those quoted by the author; in particular, the copper-free spheroidal-graphite irons showed markedly improved ductility, for example tensile strength of 28 tons per sq. in. combined with elongation of 15 per cent. could easily be achieved. Dr. Everest showed photographs of a range of typical castings now being made in various grades of the new irons, illustrating their usefulness in general engineering, their potential value for marine uses, and their suitability for heat-resisting applications. A further contribution to the discussion, by S. ARCHER, emphasized the usefulness of the improved shock-resisting qualities of the new irons, and included remarks on possible applications in the marine-engineering field. Some questions were asked with regard to the relative merits of the magnesium and the cerium treatments for production of spheroidal graphite in cast iron. Professor J. A. POPE underlined the potential value of the new irons to engineers, and pointed out some aspects of the subject on which further information was required before large-scale application could go forward at the rate which would appear to be desirable. The author's reply included reference to the limitations of the cerium process; the difficulty of testing resistance to thermal shock, and of determining the highest service temperature for the new irons; use of spheroidal-graphite cast iron for crankshafts; machining properties of the irons; costs of production, and other aspects.

Properties and Applications of Spheroidal-Graphite Cast Iron

G. L. COX: 'Properties and Application of Ductile Iron.' *Iron and Steel Engineer*, 1951, vol. 28, Dec., pp. 75-84.

A brief general description of 'ductile cast iron' is followed by a review of properties. The author stresses the wide range of combinations of strength and ductility which can be obtained in the new materials by adjustment of composition and treatment: a diagram shows the general relationships between tensile strength, yield strength and elongation, based on data collected during more than two years of commercial production.

Data are given, in 'specification' form, on the minimum mechanical properties of four grades of iron in current production: these range from a tensile strength of 90,000 p.s.i. (40 tons per sq. in.) with 2·0 per cent. elongation, to 60,000 p.s.i. (27 tons per sq. in.) with 15·0 per cent. elongation. The uses of the respective grades are discussed. The consistency with which the properties listed can be produced is demonstrated by data on test results obtained on 54 separate ladles of ductile iron produced in one month's output at a foundry operating the magnesium process.

In presenting information on the properties, attention is directed, *inter alia*, to the following points:—

Although tensile strength, yield strength and elongation decrease with increasing section-size, hardness is only slightly affected. At sub-zero temperatures the impact strength of ductile iron falls, but its superiority over ordinary cast iron at normal temperatures is maintained, and ductile iron can safely be used at −100°F. (−73°C.), a temperature considered unsafe for flake-graphite cast iron. For information on compressive strength and damping capacity the author directs attention to earlier publications. Results of recent machinability tests support the findings of earlier investigators, in showing that at given hardness levels the machinability of spheroidal-graphite iron is better than that of ordinary cast iron, although power consumption is usually greater. Spheroidal-graphite cast iron shows resistance to galling at least equal to that of flake-graphite iron, and preliminary wear tests indicate that it is pronouncedly superior in this respect. Complete evaluation of the corrosion-resisting qualities of ductile iron has not yet been possible, but the author gives some comparative data on the resistance of spheroidal- and flake-graphite irons to water, and to acid and alkaline media, indicating the likelihood of an overall resistance equal to that of good grey irons. In certain corrosive conditions, discussed by the author, it may be anticipated that ductile iron will prove superior, and it is pointed out in this connexion that Ni-Resist can be produced with graphite in the spheroidal form, thus obtaining improved mechanical and physical properties in an intrinsically corrosion-resistant iron. Spheroidal-graphite irons show considerably improved resistance to oxidation and growth.

Uses for the new irons, already established or under trial, include hammer anvils, heavy forming dies, forging-furnace doors, ingot- and billet-moulds, heavy gears and gear boxes, rolling-mill housings and drive couplings, table rolls, apron plates, roll bearings, slag pots, wire- and bar-guides and grips, wire blocks (reelers), sintering machine grates, soaking-pit covers, open-hearth roof hangers, nail-bluing tubes, clamps. Illustrations of some of these applications are included in the paper.

Endurance Limits and Damping Capacity of Spheroidal-Graphite Cast Iron

H. MAJORS: 'Dynamic Properties of Nodular Cast Iron, Part I.' *Amer. Soc. Mechanical Engineers, Paper* 51-*F*-5, Sept., 1951; 11 pp.

The tests described in this paper were made on as-cast and annealed magnesium-treated iron. The magnesium was added in the form of copper-magnesium alloy. The paper is factual in nature, reporting results of endurance tests carried out under a variety of conditions; variables studied included speed of test, and the influence of notches and grooves of various shapes.

Tables in an appendix to the paper give data on plain and alloy steels of various types, to facilitate comparison of the static and dynamic stress concentrations of steels with those of nodular-graphite cast iron.

Martensitic Transformation in High-Nickel Alloy Cast Irons

P. LAURENT and M. BATISSE: 'Study of the Martensitic Transformation in Austenitic Cast Irons.' *Rev. de Métallurgie*, 1952, vol. 49, Feb., pp. 129-39.

The authors report in detail observations on cast irons of the compositions shown below.

The dilatometric equipment used is described, with drawing, and results are given of measurements of modulus of elasticity, and of shear, bend, impact, and hardness tests. Formation of martensite was found to favour subsequent graphitization, and it was observed that on heating the irons in the martensitic condition the austenite formed differed from the original austenite, in that it was acicular in character. The authors conclude that this suggests that in the irons studied the austenite-martensite transformation is reversible, as in copper-aluminium alloys. Increasing the rate of cooling in the austenite range lowers the position of the Ar''' transformation.

T.C. %	G.C. %	Si %	S %	P %	Mn %	Cr %	Cu %	Ni %
3·00	2·47	1·95	0·027	0·044	1·00	2·20	—	20·69
3·01	2·39	1·97	0·026	0·045	1·58	2·51	5·23	14·86
3·05	2·30	2·14	0·046	0·048	0·49	—	—	16·09

Nickel-containing Cast Irons for Cylinder Liners

G. P. PHILLIPS: 'Hardened Gray Iron. An Ideal Material for Diesel Engine Cylinder Sleeves and Liners.' *Foundry*, 1952, vol. 80, Jan., pp. 88-95, 222, 224, 226, 228; Feb., pp. 106-11.

During the early development of the Diesel engines manufactured by International Harvester Company it became apparent that wear encountered with cylinder sleeves of ordinary hardness (about 200 Brinell) was excessive. An extensive programme of research and development was therefore instituted, some 18 years ago. This paper gives a comprehensive account of the main lines of the research, the conclusions drawn, the materials developed as a result of the work, and their service record. The hardened cylinder liners discussed are used in heavy-duty petrol engines employed in trucks and power units, as well as in all the Diesel engines produced by these works.

Following a brief discussion of the nature of wear and of the theories which have been advanced to explain it, the author describes the severe schedule of wear tests to which materials considered for cylinder sleeves and liners are subjected. The types which have been tested, at one or more stages of development, are listed below:—

(1) Alloyed grey cast irons, of 180-270 Brinell hardness.
(2) Hardened (heat-treated) alloyed grey cast irons of various types, having final hardness in the range 450-550 Brinell.
(3) Special heat- and corrosion-resisting high-alloy cast irons.
(4) Nitrided cast irons.
(5) Special steels: hardened graphitic steel: Ihrigized steel.
(6) Special sleeves having alloy white iron inner diameters.
(7) Hardened, unalloyed, fairly-low-carbon grey cast iron.

The author gives a detailed survey of the results of the tests, and particulars of the composition, properties and structures, with notes on conclusions drawn as to the qualities essential in materials for sleeves and liners. Methods of production for the respective components are also described. Particular attention is directed to the good service life obtained with hardened molybdenum-chromium-nickel cast iron for sleeves and liners.

CONSTRUCTIONAL STEELS

Distribution of Hydrogen in Nickel-Alloy Ingots and Forgings

J. D. HOBSON and C. SYKES: 'Distribution of Hydrogen in Large Ingots and Forgings.' *Jnl. Iron and Steel Inst.*, 1952, vol. 170, Feb., pp. 118-22.

The importance of hydrogen in steel manufacture is now widely recognized, and in recent years many papers have dealt with methods of determining hydrogen in both liquid and solid steel, and with defects which may, in part at least, be attributed to the presence of hydrogen, e.g., hair-line cracks, fish-eyes, snowflakes. Some papers have also recorded the effects of hydrogen on the mechanical properties of steel, showing the main result of its presence to be a loss of ductility. It is pointed out that this effect may be of considerable practical importance when testing specimens taken from the interior of large forgings, where the size factor prevents rapid loss of hydrogen by the diffusion normally occurring in steel products of small cross section.

Investigations into the distribution of hydrogen in ingots and forgings have previously been concerned mainly with relatively small masses of metal: the present paper, on the other hand, contains results relating to large ingots and forgings made by the acid open-hearth process. The data refer to cores taken from two ingots trepanned after annealing, an ingot cogged before trepanning, three cores taken from forgings, and one from a forged discard. The steels represented include mild steel, high-carbon low-chromium steel, and 1¾ per cent. nickel, 2¼ per cent. nickel-chromium-molybdenum and 2½ per cent. nickel-chromium-vanadium types.

The measurements made indicate that wide variation in hydrogen content exists in the centre of large ingots and forgings. Single determinations may therefore give a misleading impression of average hydrogen content.

The variation depends upon the size of the sample: it is much more severe in small specimens. Re-hydrogenation experiments demonstrated that segregation is caused by hydrogen segregation rather than by variation in hydrogen solubility. Some practical implications of the observations made are discussed.

Hydrogen Embrittlement of Steel: Literature Review

R. W. BUZZARD and H. E. CLEAVES: 'Hydrogen Embrittlement of Steel: Review of the Literature.' *Nat. Bur. Standards, Circular* 511, Sept. 24, 1951; 29 pp.

The review is classified in sections containing (1) a brief introductory discussion of the significance and effects of hydrogen in steel; (2) the chemistry of the iron-hydrogen system; (3) the effects of hydrogen on the properties of iron; (4) embrittlement caused by hydrogen from various sources. The discussion is supported by a *bibliography* of 1191 references, ranging in date from 1800 to 1949.

The review is considered to establish the fact that steel absorbs hydrogen on exposure to the gas at an elevated temperature or in the environment of a chemical reaction. Early work on effects of hydrogen centred mainly on porosity and blow-hole formation: subsequently the list of defects due to hydrogen absorption was widened to include flaking, pickling embrittlement, shatter cracks, hairline cracks, failures in welded joints, and various other types of failure in service. The data found in the literature fail to provide quantitative proof that hydrogen is the sole cause of these defects, but it is well established that when procedures for maintaining the hydrogen content at a minimum are utilized certain defects generally ascribed to presence of hydrogen can be eliminated.

Nickel-Chromium-Molybdenum Steel Bars for Springs

AMER. SOC. TESTING MATERIALS: 'Tentative Specification for Nickel-Chromium-Molybdenum Steel Bars for Springs.' *A.S.T.M. Designation A*.332-51*T*.
1951 Supplement to Book of A.S.T.M. Standards, Part 1, pp. 336-9.

Accepted by the Society, June, 1951; for abstract see *Nickel Bulletin*, 1951, vol. 24, No. 8, pp. 176-7.

Nickel-Alloy Steel Tubes for Low-Temperature Service

AMER. SOC. TESTING MATERIALS: 'Tentative Specifications for Seamless and Welded Steel Tubes for Low-Temperature Service.' *A.S.T.M. Designation A*.334-51*T*.
1951 Supplement to Book of A.S.T.M. Standards, Part I, pp. 223-30.

Accepted by the Society, June, 1951; for abstract see *Nickel Bulletin*, 1951, vol. 24, No. 8, p. 177.

Nickel-Alloy Steel Seamless Drum Forgings

AMER. SOC. TESTING MATERIALS: 'Tentative Specification for Alloy Steel Seamless Drum Forgings.' *A.S.T.M. Designation A*.336-51*T*.
1951 Supplement to Book of A.S.T.M. Standards, Part 1, pp. 313-19.

Accepted by the Society, June, 1951: for scope see *Nickel Bulletin*, 1951, vol. 24, No. 8, p. 177.

Specification for Low-Nickel-Chromium Steel for Aircraft

BRIT. STANDARDS INSTN.: 'Low Nickel-Chromium Steel.' *Specification S*.103, Dec., 1951.

Covers wire for manufacture of cold-forged bolts of $\frac{1}{2}$-in. shank diameter and over.

Composition range: carbon 0·30-0·40, silicon 0·10-0·35, manganese 0·6-0·9, nickel 1·0-1·5, chromium 0·45-0·75, sulphur 0·050 max., phosphorus 0·050 max., per cent.

Mechanical properties are specified, and details of heat-treatment are given. The composition of the steel corresponds with that of En 111.

Electric Arc Welding of Low-Alloy to High-Alloy Nickel-containing Steel

G. H. DEGROAT: 'Welding Turbine Shafts and Wheels for Jet Engines.' *Machinery (N.Y.)*, 1952, vol. 58, Jan., pp. 179-83.

One of the main components of the General Electric J-47 turbo-jet engine is a single-stage axial-flow gas turbine, consisting, principally, of a forged shaft welded to a wheel which contains the turbine blades. A weld of extremely high quality is necessary, and every stage of the process is covered by exacting specifications. The means used, at the plant of Wright Aeronautical Corporation, to meet the requirements, are described in this article.

The turbine wheel, which operates at high temperatures, is made from a 16-25-6 chromium-nickel-molybdenum steel, while the shaft, which is subject to only a relatively low temperature, is of a steel containing carbon 0·40, manganese 0·70, nickel 1·75-2·0, per cent.

Manual electric-arc welding is used, employing a flux-coated electrode, thus ensuring the control required for the production of sound and strong welds of good appearance. Equipment used and welding technique employed are described at some length, and illustrated.

Properties and Uses of Boron-Treated Steels: U.S. Experience

D. H. RUHNKE: 'Boron Steels Supplement Scarce Nickel, Moly Alloys.' *Steel*, 1952, vol. 130, Jan. 14, pp. 66, 69-70, 72, 75.

A critical appraisal of the present status of boron-containing steels, based on the experience of Republic Steel Corporation and other producers and users.

HEAT- AND CORROSION-RESISTING ALLOYS

High-Temperature Alloys in British Jet Engines

H. W. G. HIGNETT: 'High-Temperature Alloys in British Jet Engines.' *Paper presented to Detroit Chapter, Amer. Soc. Metals*, Nov. 12, 1951; 23 pp.

The paper presents a first-hand account of British developments: the information given refers solely to British jet engines now in production. It is presented in four main sections, covering, respectively

combustion chambers; stator blades or nozzle guide vanes; rotor discs; and moving blades, or buckets.

Combustion Chambers

The type of combustion chamber adopted by Rolls-Royce for the 'Derwent' engine is illustrated and described, in order to give a broad outline of the component parts and of the service conditions involved, but it is emphasized that minor variations in design used by various engine builders appreciably affect working conditions (in the head, body or flame tube, and outer casing), and, as a result, the nature of the failures most likely to occur in the respective parts.

A list is given of the nominal compositions of flame-tube alloys used in British engines (Nimonic 75, Nimonic F, Inconel, and Red Fox 31 and 33). Nimonic 75 has provided by far the greatest amount of service experience in British engines, and data at present available are insufficient to permit reliable assessment of the probable behaviour of the other alloys mentioned. In discussing the properties of the flame-tube materials, particular attention is directed to the importance of thermal-shock resistance. Apparatus used for determining this property is described and illustrated.

Stator Blades or Nozzle Guide Vanes

In this connexion also the importance of resistance to thermal shock is emphasized, and reference is made to means for obtaining improved resistance by means of design modifications, as well as by use of material of suitable composition. The choice between wrought and cast stator blades is influenced largely by factors of design: cast alloys are the more popular in British engines. H.R. Crown Max, which is characterized by excellent castability, is very generally used: in some engines cast Nimonic 80 is used, and in others the blades are machined from rolled bar of this alloy.

Turbine Discs

Until recently the very large majority of turbine discs have been made from austenitic steels, of which a particularly successful type has been the G.18B composition, but it appears likely that in the future ferritic steel discs will be almost universally adopted. Consideration is therefore given to the properties of such steels, as typified by low-chromium-molybdenum, molybdenum-vanadium, and chromium-molybdenum-tungsten-vanadium compositions, and high-chromium steels containing small percentages of molybdenum, vanadium and niobium. The importance of correct balance of composition and heat-treatment, in order to ensure production of optimum properties in these steels, is discussed, and fundamental facts with regard to constitution and structure, which are gradually emerging from the somewhat empirical development of the steels, are considered. Reference is given to some major contributions to the literature of the subject.

Turbine Rotor Blades

The primary requirements which must be satisfied by materials for rotor blades are listed as:—

(1) Oxidation resistance and freedom from intergranular attack.
(2) High creep strength over a range of temperatures.
(3) High fatigue strength at operating temperatures.
(4) Freedom from tendency to embrittlement.
(5) Reasonable ease of hot working and machining.
(6) Reproducibility of properties, especially creep properties, under economic conditions of works' production.

All the moving blades of all British aircraft gas-turbines in current production are of wrought Nimonic 80, 80A or 90, or, in multi-stage turbines, of a combination of these alloys. These alloys, based on the 80-20 nickel-chromium series, are discussed at some length by the author, who has been closely associated with the research involved in their development. In Nimonics 80 and 80A the matrix consists of a solid solution of chromium in nickel, and in Nimonic 90 cobalt replaces 20 per cent. of the nickel. In all three alloys the matrix is hardened by the controlled precipitation of a nickel-aluminium-titanium compound of the type Ni_3 (TiAl). Reference is made to the very extensive research which has been carried out on these and related alloys; typical creep properties are graphically illustrated, and a review is made of the factors which are of major importance in ensuring consistent production of the required properties. The following variables are kept under strict control: purity of raw materials; melting and deoxidation practice; fabrication conditions. The quality of each heat of the Nimonic alloys and its ability to meet stringent governmental specifications are checked before acceptance, by means of a creep test carried out on a bar forged from a small pilot ingot. The factors influencing high-temperature fatigue strength of the Nimonic alloys is also discussed in this paper, including consideration of the reduction of fatigue life occurring after onset of tertiary creep, grain size as related to fatigue-resistance, and the detrimental effect resulting from modification of the surface layers of the alloys by cold-work and heat-treatment.

In closing, the author draws attention to the peculiarly close inter-relation of the work of the engineer and the metallurgist involved in the development of gas turbines: 'a classic example of fruitful collaboration'. It is surmised that the engines of the future will employ higher gas temperatures, but the extent to which this modification will bring in its train a demand for improved heat-resisting materials will depend largely on the advances made in design, including methods of cooling.

Nickel Alloys used for Gas-Turbine Blading

H. W. KIRKBY: 'Manufacture of Gas Turbine Blades.' *Metal Treatment and Drop Forging*, 1952, vol. 19, Feb., pp. 61-6.

A review of the compositions and properties of alloys for gas-turbine blading, of production methods used, heat-treatments applied, and inspection methods.

It is pointed out that the majority of short-time applications are for aero-engines, and the conditions are such as to require materials capable of withstanding exceptionally high stresses at temperatures up to, or even beyond, 800°C. For this type of service most iron-base alloys are inadequate, and the majority of the materials used are of high-nickel and/or cobalt base, with substantial amounts of chromium. In

Great Britain the Nimonic alloys are being used exclusively for moving blades in aircraft engines. Compositions of Nimonic 80A and 90 are tabulated, and details are given of typical properties of the two materials. Reference is also made, in the group of materials used for short-time high-temperature applications, to S 816, G.32, R.ex 448 and 467, FCB(T), and 326 and 337 alloys. Some data on the properties of the two R.ex alloys are given.

In land- and marine-service applications of gas turbines the conditions are less severe than in the aircraft engines, but the service lives required are very much longer. For such applications a number of iron-base alloys have proved suitable. In this article the author discusses specifically some of the materials with the development of which he has been closely associated: for a fuller discussion of the subject, reference is directed to papers contained in the Symposium of High-Temperature Steels and Alloys for Gas Turbines (*Iron and Steel Institute Special Report No.* 43), of which abstracts are given in *Nickel Bulletin*, 1951, vol. 24, No. 6, pp. 116-28.

In the category of ferritic steels, particular attention is directed to high-chromium steels containing small amounts of molybdenum, of the R.ex 448 type. Short-time creep properties of this type of steel are shown to compare favourably with those of 18-12 chromium-nickel steels, but with increase in creep-testing time the ferritic steel shows to progressively less advantage, and it is the author's experience that no stainless-type ferritic steel available has creep properties as good as those of stabilized 18-12 steels for longer periods, e.g., 10,000 hours or more, for service at temperatures of 550°-650°C.

Austenitic steels within the author's particular range of interest are discussed in four groups: (1) 18-12 chromium-nickel stabilized with titanium; (2) 18-12 chromium-nickel stabilized with niobium; (3) 326 steel, a complex 16-17 chromium-nickel steel containing cobalt, molybdenum and niobium, and (4) 337 and R.ex 467 steels, the former being a titanium-stabilized complex chromium-nickel steel developed to give very high creep-resistance, particularly over long periods, and the latter a modification of 337, recently introduced as a contribution to alloy economy with only slight lowering of creep-resistance. The characteristics of the respective grades are individually discussed.

In the closing sections of the article consideration is given to the methods of manufacture and treatment of gas-turbine blading made from the materials described above. The advantages of drop-stamping are emphasized, and stages in stamping are illustrated, together with photographs of blades in the finish-machined condition. Behaviour of the austenitic and the ferritic steels in stamping operations are discussed.

Creep-resisting materials of the types under consideration usually require higher temperatures of heat-treatment than those used for lower-alloy steels. Treatments used for Nimonic alloys, and for the 18-12 types of steels are quoted as typical. The article closes with short notes on methods of inspection and testing applied to gas-turbine blading, and with a brief indication of the possible future trend of development.

S.A.E. (A.M.S.) Specifications for Corrosion- and Heat-Resisting Materials

The following specifications are among a series of new and revised schedules recently issued by the Society of Automotive Engineers:

A.M.S. 5535 (1.12.51) Alloy Sheet and Strip, Corrosion and Heat Resistant.

Composition Limits	%
Carbon	0·20-0·30
Manganese	2·00 max.
Silicon	1·00 max.
Phosphorus	0·040 max.
Sulphur	0·030 max.
Chromium	24·00-27·00
Nickel	18·50-21·50
Molybdenum	3·50-4·50
Tungsten	1·70-2·30
Columbium+Tantalum	1·80-2·40
Iron	5·00 max.
Cobalt	38·00 min.

Heat-treatment comprises heating to 2150°F. (1175°C.), followed by air cooling. Tensile, hardness and bend tests are specified.

A.M.S. 5679 (1.12.51) Alloy Wire, Corrosion and Heat Resistant.

Composition Limits	%
Carbon	0·10 max.
Manganese	1·00 max.
Silicon	0·75 max.
Sulphur	0·015 max.
Chromium	14·00-17·00
Nickel+Cobalt	70·00 min.
Cobalt, if determined	1·00 max.
Columbium+Tantalum	4×Si min.
Iron	6·00-10·00
Copper	0·50 max.

The material is primarily for use as bare-wire filler metal for inert-gas metal-arc welding and atomic-hydrogen welding.

A.M.S. 5728 (1.12.51) Steel, Corrosion and Heat Resistant (Kellogg Electric Ingot Process).

Composition Limits	%
Carbon	0·12 max.
Manganese	2·00 max.
Silicon	1·00 max.
Phosphorus	0·030 max.
Sulphur	0·030 max.
Chromium	15·00-17·50
Nickel	24·00-27·00
Molybdenum	5·50-7·00
Nitrogen	0·10-0·20
Copper	0·50 max.

The material is for use primarily as turbine wheels and discs, at temperatures up to 1350°F. (735°C.).

Incoloy: Composition and Properties

'New Heat-Resistant Alloy is Developed.' *Inco*, 1951-52, vol. 25, No. 2, pp. 13-14.

The nickel-chromium-iron alloy Incoloy, the development of which was briefly announced in *The Nickel Bulletin*, 1951, vol. 24, No. 9-10, p. 207, contains approximately 34 per cent. of nickel, and 21 per cent. of chromium, balance iron.

Properties typical of the new alloy, in various forms, are shown in the table on p. 111.

Laboratory studies have shown that the thermal coefficients of expansion of Incoloy are only slightly

Mechanical-Property Ranges at Room Temperature

Form and Condition	Tensile Properties						
	Tensile Strength		Yield Strength		Elongation % in 2 in.	Hardness	
	p.s.i.	t.s.i.	p.s.i.	t.s.i.		Brinell (3,000 kg.)	Rockwell
Rod and Bar							
Cold-drawn							
Annealed	75,000-100,000	33·5-45·0	30,000- 55,000	13·5-24·5	50-30	120-170	66-86B
As-drawn	100,000-150,000	45·0-67·0	80,000-125,000	35·75-55·75	30-10	180-290	90B-30C
Hot-rolled							
Annealed	75,000-100,000	33·5-45·0	30,000-55,000	13·5-24·5	50-30	120-170	66-86B
As-rolled	80,000-120,000	35·75-53·5	35,000-90,000	15·5-40·25	50-25	135-220	74-96B
Forged	80,000-120,000	35·75-53·5	35,000-90,000	15·5-40·25	50-25	135-220	74-96B
Wire							
Cold-drawn							
Annealed	75 000-105,000	33·5-46·75	25,000-55,000	11·0-24·5	50-25		
Plate							
Hot-rolled							
Annealed	75,000-105,000	33·5-46·75	30,000-55,000	13·5-24·5	50-30	120-180	
As-rolled	80,000-120,000	33·75-53·5	35,000-90,000	15·5-40·25	50-25	135-220	
Sheet							
Cold-rolled							
Annealed	75,000-100,000	33·5-45·0	30,000-55,000	13·5-24·5	50-30		88B (max.)
Deep drawing and spinning quality	75,000-100,000	33·5-45·0	30,000-45,000	13·5-20·0	55-35		80B (max.)
Strip							
Cold-rolled							
Annealed	75,000-100,000	33·5-45·0	30,000-50,000	13·5-22·25	50-30		84B (max.)
Deep drawing and spinning quality	75,000-100,000	33·5-45·0	30,000-45,000	13·5-20·0	55-35		80B (max.)
Tubing							
Cold-drawn							
Annealed	75,000-100,000	33·5-45·0	30,000-55,000	13·5-24·5	50-30		88B (max.)

higher than those of Inconel, and indicate that the new alloy should have high resistance to cracking under alternations of temperature. It shows no tendency to embrittlement after prolonged exposure to intermediate temperatures. At room temperature the tensile properties and hardness of Incoloy, in the annealed condition, fall within the range typical of Inconel. Long-time creep and stress-rupture tests are not yet complete, but early indications are that the high-temperature properties of Incoloy will be slightly below those of Inconel. Work-hardening characteristics of the two alloys are closely similar: fabricators accustomed to handling Inconel should therefore experience little difficulty in handling Incoloy.

Effect of Ageing on Creep Properties of N-155 Alloy

D. N. FREY, J. W. FREEMAN and A. E. WHITE: 'Fundamental Effects of Ageing on Creep Properties of Solution-Treated Low-Carbon N-155 Alloy.' *Nat. Advisory Committee for Aeronautics, Report* 1001, 1950; 30 pp.

The report covers the first part of an investigation being made into the fundamental behaviour, at high temperatures, of austenitic alloys designed for use in aircraft propulsion systems. (Reports on later stages of the research have already been published: see for example, papers abstracted in *Nickel Bulletin*, 1952, vol. 25, No. 1, pp. 17-18 and No. 3, pp. 73-5).

Previous investigations had indicated the effects of prior processing and heat-treatment conditions on the high-temperature properties of the low-carbon type of N-155 alloy and various other austenitic alloys (*N.A.C.A. Tech. Note* 1867, 1949; see also *Proc. Amer. Soc. Testing Materials*, 1949, vol. 49, pp. 619-45: *Nickel Bulletin*, 1949, vol. 22, Nos. 8-9, p. 143). In the work recorded in the 1950 report the basic assumption was that the behaviour of alloys at high temperatures is dependent on their microstructure and the lattice conditions of the matrix. The programme was therefore designed for the study of these two characteristics in N-155, as influenced by heat-treatment, chemical composition, and exposure to temperature and stress. Bar-stock material, solution-treated at 2200°F. (1204°C.) was aged for periods up to 1,000 hours, at 1200°, 1400° and 1600°F. (648°, 760° and 870°C.). Optical- and electron-microscope techniques, and separation and analysis of microconstituents, were used to examine structural conditions: the lattice conditions of the matrix, particularly the strain present, were measured by X-ray diffraction methods, and creep and rupture properties were correlated with the physical state of the alloy in the various conditions of ageing.

The conclusions drawn are:—

(1) Ageing resulted in progressive lowering of short-time creep-resistance, due to removal, from solid solution, of large-radius or substitutional atoms, by precipitation.

(2) Short-time ageing resulted in marked increase in short-time rupture strengths, through the growth of a grain-boundary phase which eliminated intergranular cracking. Long-time ageing produced little further change in short-time rupture strength.

(3) Because ageing lowered the creep resistance, while raising the rupture strength, aged material exhibited greater ductility before fracture than unaged material.

It is emphasized that the findings should *not* be considered as generally applicable to long-time strength properties, *or* to strength at other temperatures, *or* to the same alloy in other conditions of heat-treatment.

Thermal Shock Testing of High-Temperature Materials

M. BENTELE and C. S. LOWTHIAN: 'Thermal Shock Test on Gas Turbine Materials. A Study of the Effects of Severe Temperature Fluctuations on Rotor Blades and Nozzle Segments.' *Aircraft Engineering*, 1952, vol. 24, Feb., pp. 32-8.

Resistance to thermal shock has recently been increasingly recognized as a factor in the life of high-temperature materials, especially of those operating in service in which it is impossible to avoid very rapid alternations of temperature, e.g., aircraft gas turbines. Various methods for testing resistance of materials to thermal shock have already been suggested and applied, but quantitative and comparable data are at present lacking.

In this paper the authors give (1) a general review of the current stage of development of the subject, from a theoretical standpoint, (2) a critical survey of published thermal-shock-test procedures and results, and (3) a summary of data obtained in thermal-shock tests on a series of high-temperature alloys. They propose two new forms of thermal-shock test, of which details are given, with diagrams.

Welding of Nickel-containing Alloys used in Gas Turbines for Aircraft

H. E. LARDGE: 'Welding on Gas Turbine Engines for Aircraft.' *Trans. Inst. Welding*, 1951, vol. 14, June, pp. 85-91.

The paper describes welding methods employed in Great Britain; it is based mainly on the experience of Messrs. Joseph Lucas (Gas Turbine Equipment), Ltd. An introductory section describes (with drawing) the essential features of a typical jet-propulsion engine, with some remarks on the nature of the materials used in the various components: combustion chambers, nozzle assemblies, exhaust units and other components of engines now in production are illustrated. The nature of the materials used for the respective parts, e.g., Nimonic 75 for flame tubes, and chromium-nickel steel for jet pipes and other parts, is discussed in relation to their welding characteristics, and the physical and mechanical properties of these materials affecting welding are tabulated. It is pointed out that the main factors affecting fusion welding are the high rates of thermal expansion and the low thermal conductivity of the high-alloy materials, as compared with the corresponding properties of mild steel. In resistance welding the important difference is the high electrical resistance and low thermal conductivity, which allow of welding the alloy materials with less electrical energy than is required for welding unalloyed steel.

The applicability of the various methods of welding, to joining of the high-temperature materials, is reviewed. Fusion welding is used for butt and fillet welds, as design considerations dictate; some edge welding by melting adjoining edges is being developed. As more powerful engines are developed, thicker materials are being introduced, and fusion-welding methods are being increasingly adopted. Electric-arc is preferred to flame welding, since the more closely localized concentration of heat reduces distortion to a minimum. Torch-brazing, with silver-brazing alloys, is used, generally in conjunction with spot welding, where temperatures permit. The carbon-arc process has been preferred to the oxyacetylene process for material of the thinner gauges, due to the lower distortion: it has been used, for example, for welding discharge-nozzle components and for assembly, but is now being generally replaced by the argon-arc method, of which the author gives essential particulars. A set-up for argon-arc welding is illustrated, and a typical argon-arc weld in Nimonic 75 is shown. Until recently the metallic-arc process has not found many applications in the class of work under review, but with the trend towards the use of thicker materials it is being increasingly employed. The application of resistance welding to the combustion equipment of gas-turbine engines is considered to be a specially interesting development. Seam welding, in particular, has proved to be a quick, reliable, and consistent means of joining this class of sheet-metal work, and many new designs have been based on this process. It is believed that the relatively high production figures attained towards the end of the war period would have been very difficult to reach without the use of resistance welding. The fundamental principles of resistance welding are outlined by the author, and some particulars are given of the nature of the electrodes used and the technique of welding, with special reference to seam welding.

Electric Arc Welding of Low-Alloy to High-Alloy Nickel-containing Steel

See abstract on p. 108.

Nickel-Alloy Steel Seamless Drum Forgings

See abstract on p. 108.

Titanium-Carbide-base Cermets with Nickel-Aluminium Binder

C. C. MCBRIDE, H. M. GREENHOUSE and T. S. SHEVLIN: 'A Preliminary Study of the Oxidation and Physical Properties of TiC-base Cermets.' *Jnl. Amer. Ceramic Soc.*, 1952, vol. 35, Jan. 1, pp. 28-32.

Research on development of materials for use in gas turbines is currently guided by three immediate goals: (1) longer life at temperatures of 1500°-1800°F. (815°-980°C.); (2) practical life at temperatures of 1800°-2400°F. (980°-1315°C.); and (3) short, but useful, life at temperatures above 2400°F. (1315°C.). The strategic character of raw materials available, possible production techniques, and cost are considerations governing selection. Some of the compounds of the refractory materials, e.g., tungsten carbide or titanium carbide, are known to possess wear-resistance and strength properties of a high order at elevated temperatures, but, as compared with metallic materials, they have much lower resistance to thermal and mechanical shock. Optimum properties may, it is hoped, be obtained by a combination of the refractory compounds with metal binders.

Evaluation of existing data has indicated titanium carbide to be the most promising material as the major constituent for such composites, and this paper deals with a preliminary investigation of titanium carbide-base cermets containing chromium, iron, cobalt, nickel, nickel-aluminium (70-30 alloy), ferrosilicon, or Duriron as binders. The specimens were evaluated on the basis of modulus of rupture at 75° and 1800°F. (24° and 982°C.), oxidation-resistance at 2,000°F. (1093°C.), and the degree of chemical reaction between the carbide and the metal. The oxidation products were studied metallographically and by X-ray diffraction, in order to determine a qualitative mechanism of oxidation. The results are fully reported.

The data show that the nickel-aluminium cermets are outstandingly promising: a cermet containing 90 per cent. titanium carbide with 10 per cent. nickel-aluminium showed a modulus of rupture at 1800°F. (982°C.) of 72,500 p.s.i. and the oxidation tests (100 hours at 2000°F. : 1093°C.) showed a loss of only 0·082 g./cm². Investigation of the oxidation products formed on the cermets led to the conclusion that oxygen diffusion is the governing factor in the oxidation mechanism.

Production of Stainless-Steel Tubing by the Ugine-Sejournet Extrusion Process

'Stainless Tubing Hot Extruded by French Process.' *Steel*, 1952, vol. 130, Jan. 21, p. 79.

The Babcock and Wilcox Company report initial production of stainless-steel tubing by the Ugine-Séjournet process, which is claimed to make possible extrusion of hollow and solid sections of metals that are difficult to forge. The use of this process also permits production of much finer and more complicated sections than could previously be produced even in the more readily forgeable steels. The distinguishing feature of the Ugine-Séjournet process is the use of glass, which acts, for an extremely short time, both as lubricant for the hot-worked metal and as insulator to protect the die system.

The first lot of extruded seamless tubing produced was of the 18-8 chromium-nickel type of steel. The extruded tubes were Roto-Rocked.

Nickel and Nickel Alloys in Fluorine-Production Equipment

H. R. LEECH: 'The Development of Fluorine Production.' *Research*, 1952, vol. 5, Mar., pp. 108-15.

The article describes the methods commonly used for production of fluorine, and discusses the handling of it. It is pointed out that only in recent years has there been a commercial demand for fluorine: the need for uranium hexafluoride for use in isotope separation during the war was the primary factor in initiating large-scale production, and since then interest has

been stimulated by discovery of new fluorine compounds.

The writer describes processes involving the use of cells of high- and medium-temperature types, and discusses the current position with regard to large-scale production and availability of fluorine. Materials involved in fluorine production are also reviewed, including metals and constructional materials employed in plant and equipment. Some of the observations made with regard to metallic materials are given below:—

'There is considerable misunderstanding with regard to the corrosive attack on metals of fluorine and hydrogen fluoride. Water is the real enemy, and in the absence of water corrosion is slight. Thus, most ordinary metals stand up at ordinary temperatures very well. With iron, copper, nickel, aluminium, and magnesium and their alloys, corrosion is negligible, and this persists up to 250°C. at least. Even up to 400°C. corrosion is not very great . . . For temperatures up to 600°C. nickel shows an excellent resistance and it can be used for short periods at temperatures up to 700°C. Platinum corrodes very rapidly in fluorine at about 400°C., and the soft metals, tin, lead, and solder, are rapidly attacked by hydrogen fluoride: their use is not recommended.'

In description of the cells used for production of fluorine, mention is made of the use of Monel equipment in the high-temperature type, and of nickel anodes as a feature in the medium-temperature cell process. The closing section of the paper contains discussion of industrial development to date, with emphasis on potential expansion which may result from the more intensive research now being prosecuted on fluorine and its compounds. The review is supported by a *bibliography* of 27 references. A later article will discuss some of the more interesting advances made in fluorine chemistry.

Resistance of Nickel-containing Materials to Hydrogen Peroxide

Materials of Construction *vs.* Hydrogen Peroxide.' *Chemical Engineering*, 1951, vol. 58, Oct., pp. 263-4, 266-8, 270-1.

One of the 'Corrosion Forum' series. The behaviour of the following materials in contact with hydrogen peroxide is summarized: aluminium; stainless steel; tin; tantalum; lead; iron; copper and copper-base alloys; rubber, plastics and coatings; wood, Transite and concrete; nickel and nickel alloys; Worthite; Chlorimet alloys; carbon and graphite; cements; Durimet 20.

Stainless Steels

Chromium-nickel steels of the 18-8 and related types are highly resistant to hydrogen peroxide under a wide range of conditions, but such materials have a mildly catalytic action on decomposition of peroxide and are not recommended for long-time storage of concentrated solutions. When contact is of short duration these steels are suitable for use with solutions up to 50 per cent. concentration, and they are especially recommended for handling dilute solutions, such as those used in bleaching operations. Stainless-steel storage equipment should be passivated with nitric acid before use in contact with hydrogen peroxide.

Copper and Copper Alloys

Copper is a very active decomposition catalyst. Copper and its alloys are therefore not recommended for contact with hydrogen peroxide under any conditions.

Nickel and Nickel Alloys

Nickel, Inconel and Monel are highly resistant to both neutral and alkaline hydrogen-peroxide solutions. Inconel is also resistant to some acid solutions, but nickel and Monel would be attacked under such conditions. All three materials are in common use for handling bleach solutions, e.g., in textile plant.

Nickel and Inconel have only very slightly catalytic effect on decomposition of pure hydrogen peroxide, and may satisfactorily be used for handling all concentrations, in a wide range of applications. They would, however, generally not be used in preference to high-purity aluminium for storage and transport of concentrated hydrogen-peroxide solutions where complete resistance to decomposition over long periods is essential. Monel, due to its copper content, has a significant catalytic influence on decomposition of strong solutions: its use is therefore generally limited to the more dilute solutions, as employed in bleaching.

Worthite

It is stated that many years of satisfactory performance have resulted in the recognition of Worthite as one of the best materials for handling hydrogen peroxide below 50 per cent. concentration.

Chlorimet Alloys

Very little testing has yet been done with Chlorimet 3 (nickel 60, chromium 18, molybdenum 18, iron 3 max., per cent.) against hydrogen peroxide, but, due to its high chromium content, good resistance would be anticipated. The fact that other less-highly-alloyed materials of construction can suitably be used for this purpose makes the use of Chlorimet 3 uneconomic. Chlorimet 2 (nickel-molybdenum alloy containing no chromium), would give only poor resistance to corrosion by hydrogen peroxide, and should not be considered for such service.

Durimet 20

This steel, which contains nickel 29, chromium 20, molybdenum 1·75 min., copper 3·5 min., per cent., appears to offer no advantage over straight 18-8-type steels for handling the common hydrogen-peroxide solutions. It has nevertheless been used to a considerable extent for handling bleach solutions.

Corrosion-Resisting Materials for Use in Oil Refineries

B. B. MORTON: 'Selecting Alloys to Resist Corrosion.' *Petroleum Processing*, 1951, vol. 6, Nov., pp. 1233-5.

This paper comprises a condensed series of recommendations of materials which can be used to resist specific types of corrosive attack occurring in various parts of petroleum-refinery plant. The subject is dealt with in sections relating to—

(1) *High-Temperature Corrosion* (attack by sulphur

compounds, naphthenic acid, phenol, furfural, vanadium pentoxide).

(2) *Corrosion below* 500°*F.* (attack by acid and alkaline solutions; corrosion in plant operations involved in manufacture of petrol, e.g., in the distillation, catalytic refining, isomerization, alkylation and polymerization stages ; corrosion in plant used in manufacture of lubricating oil, e.g. by organic or chlorinated solvents; and corrosion in condensing and collecting equipment, e.g., pumps, etc. handling acid and other corrosive solutions).

The many uses of the nickel-chromium stainless steels, Monel, Inconel, Ni-Resist, and other nickel-containing materials are indicated.

Corrosion-Resisting Characteristics of Stainless Steel and Other Materials

'Comparison of Corrosion Properties of Zirconium, Titanium, Tantalum, Stellite No. 6, and Type 316 Stainless Steel.' *Materials and Methods*, 1952, vol. 35, Jan., pp. 115-17.

Tabular comparison (qualitative only) of the resistance of the materials mentioned, to corrosion by 34 different reagents. *Bibliography* of 21 references gives the source of the data presented.

Accelerated Corrosion Testing of Nickel-Chromium Coatings

See abstract on p. 98.

Brazing of Stainless Steel without Flux

F. W. BEALL: 'Stainless Brazed without Fluxing.' *Steel*, 1952, vol. 130, Jan. 14, p. 57.

This note describes developments by Armco Steel Corporation, arising out of a need to use a brazed stainless-steel assembly to replace a brass part, without materially changing furnace equipment or brazing technique. The main problem was the use of a protective gas consisting of combusted natural gas and air, in a ratio of three parts air to one part of natural gas, an atmosphere which, although correct for brazing either brass or steel, is not suitable for use with stainless steel.

Experiments showed that by iron plating the stainless steel it could be made to behave like iron or steel during a furnace-brazing operation. Best results were obtained by using a thickness of 0·2-0·3 mils iron on 302 nickel-chromium steel, and copper-brazing at 2150°F. (1175°C.). Laboratory work has been concentrated on iron coatings, but it is anticipated that coatings of nickel or cobalt would function equally successfully.

Before plating, the stainless steel is subjected to an activating treatment, consisting of anodizing in a solution containing (by weight) 30 per cent. sulphuric acid, 10 per cent. sodium sulphate and 0·05 per cent. sodium chloride, followed by a short cathodizing cycle. After cold-water rinsing the parts are transferred as rapidly as possible to the plating bath, which is of the following composition: $FeCl_2$. $4H_2O$, 40 oz./gal.; $CaCl_2$, 45 oz./gal. Examples of brazed work obtained after this cycle of treatment are shown in the note.

Technique and Applications of the Salt-Spray Test

See abstract on p. 94.

Corrosion of Welded Austenitic Steels by Concentrated Nitric Acid

H. T. SHIRLEY and C. G. NICHOLSON: 'Corrosion of Welded 18-8 Type Chromium-Nickel Steels in Concentrated Nitric Acid.' *Jnl. Iron and Steel Inst.*, 1952, vol. 170, Feb., pp. 111-18.

During the past 20 years large tonnages of titanium-stabilized 18-8 chromium-nickel steel have been used in plant employed in manufacture, storage, and use of nitric acid. A large proportion of this plant has been of welded construction, and the few unexpected failures which have occurred have been with welded equipment working in severe conditions. The main object of the work reported in the present paper was the study of typical failures, and development of the composition of steel best suited to give satisfactory service under such conditions. Investigation of test methods and correlation of the results given by them with observations on service failures showed that exposure to boiling 70 per cent. nitric acid might be used as an accelerated test, to indicate liability to breakdown of the type found in service equipment.

A detailed report is given of experiments which included investigation of the influence of chromium and nickel content (within the broad '18-8' range), the effect of titanium *vs.* that of niobium as stabilizer, and the influence of heat-treatment, on susceptibility to corrosion and response to sensitization treatment. The results lead to the following conclusions:—

The attack by concentrated nitric acid which causes early failure in welded titanium-stabilized chromium-nickel steels is of an intergranular type. In duplex steels the attack is more severe at the γ-δ boundaries, resulting in initial removal of the δ-phase material. Dislodgement of austenite grains which eventually occurs is found in material showing no indication of the presence of δ-phase.

The forms of intergranular attack occurring under the special conditions examined and used in the laboratory tests occurred in steels which behaved satisfactorily in the standard acidified copper-sulphate intergranular-corrosion test and in a wide variety of service conditions. Severe intergranular attack of this type is apparently caused only by nitric acid.

In the boiling 70 per cent. nitric-acid test severe selective attack near welds occurred in all the titanium-stabilized steels tested. It did not occur in similar steels stabilized with niobium, although such steels were found to be liable to severe intercrystalline attack after solution treatment at or above 1150°C. followed by prolonged sensitization (24 hours) at 650°C.

Severe attack on welded titanium-stabilized steels occurred in zones which had been subjected to combinations of heat-treatment similar to those producing general susceptibility to intergranular attack in unstabilized 18-10 chromium-nickel steels. Unwelded samples showed maximum susceptibility after heat-treatment at 650°- 750°C. The effect of treatments of 5-minutes' duration in this range, although relatively

small in samples previously solution-treated at 1050°C., became increasingly severe as the temperature of the solution treatment was raised to 1250°C. After treatment at or above 1350°C. air-cooling 10-gauge sheet was sufficient to induce appreciable sensitivity. The existence of a sensitized zone immediately adjacent to weld metal is therefore to be expected.

Direct attack by boiling 70 per cent. nitric acid on precipitated grain-boundary carbides appears to be slow, and is not a primary cause of intergranular failure. It was observed that massive carbides in unstabilized 18-10 chromium-nickel steels examined were lost mainly by undermining and dislodgement, in a manner similar to the loss of the δ-phase material from the duplex titanium-stabilized steels. The most damaging attack was found to be produced by an intergranular channelling action, and it was observed that nitric acid cut much wider channels than the sulphuric-acid/copper-sulphate solution. In conditions which favoured attack by the latter solution the penetrating action of the nitric acid was relatively slow, but treatments which produced practical immunity to sulphuric-acid attack resulted in a much smaller improvement in resistance to attack by nitric acid.

It is concluded that carbide stabilization by titanium is much less effective than that conferred by niobium. Although this difference is not significant under most service conditions, with concentrated nitric acid at high temperatures only niobium-stabilized steels should be used. The authors consider that the results justify the conclusion that although niobium-stabilized steels are not immune from intercrystalline attack in the acid under all conditions of heat-treatment, steels containing 18 per cent. chromium with 8-13 per cent. of nickel and having a 10:1 niobium-carbon ratio should be free from the adverse effects of welding, including the double 'heat-treatment' involved in application of sealing welds.

Electrolytic Polishing of Stainless Steels

'Electrolytic Polishing. A Process for Treating Stainless Steels and Irons.' *Automobile Engineer*, 1952, vol. 42, Feb., p. 56.

Note on the advantages of the Electropol process. It is stated that relatively low current densities are employed, and that the solution, which is completely stable, is prepared from cheap and readily available chemicals. No details are given of the composition of the bath. The wide range of potential application of the process is emphasized, also economies which may be effected by its use.

Determination of Iron in High-Nickel Alloys

F. CASSY: 'Determination of Iron in High-Nickel Alloys.' *Bull. Inst. Metals*, 1952, vol. 1, Feb., p. 45.

The following method is recommended as rapid and accurate: 'A 0·5-g. sample of alloy is weighed into a 600-ml. conical beaker, and is dissolved in 30 ml. of aqua regia. 30 ml. of 'Spekker acid'* is added and the solution is evaporated to fumes. After slightly cooling, 60 ml. of water is added and the beaker is heated to re-dissolve the residue. When solution is complete, the beaker is cooled and the contents are diluted to 500 ml. in a graduated flask.

A 50-ml. fraction is diluted to 500 ml. in a graduated flask, after addition of 20 ml. of 50 per cent. citric acid. Two 50-ml. fractions (A and B) are then taken and to each is added 10 ml. of 50 per cent. ammonia. To A is then added 10 ml. of thioglycollic solution* from a burette. Both fractions are diluted to 100 ml. in graduated flasks and their absorption values are read (setting W-W 1·20, mercury vapour lamp, Ilford 605 filters), the difference in the readings being a measure of the amount of iron present. For 0-8 per cent. iron a 4-cm. cell is used; for 8-10 per cent. iron a 2-cm. cell, etc. The instrument recommended is a Hilger 'Spekker'.

A graph is constructed, using pure iron, under the conditions described above, and covering the range required. From such a graph the percentage of iron in a sample can be calculated from the absorption values.

The method is referred to as being specially useful for nickel-base alloys containing substantial percentages of chromium and iron, but it is also applicable to many other alloys.

* *Spekker Acid.* Made by adding 200 ml. of water, 60 ml. of concentrated sulphuric acid and 60 ml. phosphoric acid, cooling, and diluting to 400 ml.

* *Thioglycollic solution.* Made by diluting 50 ml. thioglycollic acid to 500 ml.

Determination of Cerium in Austenitic Nickel-Chromium and other Steels

C. M. JOHNSON: 'Rapid Analysis Determines Cerium in Steel.' *Iron Age*, 1952, vol. 169, Jan. 17, pp. 94-6.

Full details of procedure are given for a method developed initially for estimation of cerium in 18-8 chromium-nickel steels. It involves precipitation with dry sodium-peroxide powder, from acid sulphate solution.

Production of Nickel-Chromium-Molybdenum Steel Powder for Compacting

A. H. GROBE and R. HOFFMAN: 'Stainless Steel Powder for Mechanical Parts.' *Product Engineering*, 1951, vol. 22, Dec., pp. 168-72.

The article describes a steel powder of Type 316 composition (carbon 0·1-2, nickel 11, chromium 17, molybdenum 2·5, silicon 2·5, per cent. approx.), produced by water-jet disintegration of molten steel and subsequent de-watering and screening. Shape and size of the powder particles is controlled by adjustment of the jet stream. Mode of production ensures retention of the composition of the original melt, and the powders are mixed, for sintering, to ensure a suitable proportion of particles having relatively smooth surfaces with some irregularly shaped particles, a mixture which has been found to give specially good results for moulded compacts.

Carbide die parts are required; stearic acid, stearates and waxes are suitable lubricants, and the sintering atmosphere should be highly reducing and the dew point very low.

Laboratory tests carried out by Vanadium Alloys Steel Company, on powder compacts so made, are

reported in a series of graphs contained in this article, and the structure obtained in the stainless-steel powder parts is illustrated by photomicrographs. The compacts were prepared from -100 mesh powder, compacted at 30-50 tons per sq. in. and sintered for 45 minutes at 2100°-2350°F. (1150°-1285°C.). The conclusions reached from the tests made are summarized below:—

(1) The powder can be successfully sintered at temperatures as low as 2100°F. (1150°C.) with resultant tensile strengths, for single sintering treatments, of 17,000-29,000 p.s.i. (7·5-13 tons per sq. in.) and elongations of 5-6 per cent.

(2) The maximum tensile properties obtained by double sintering at 2350°F. (1285°C.), with a coining operation between the sintering treatments, are 56,000-76,000 p.s.i. (25-34 tons per sq. in.), with elongations of 17-31 per cent.

(3) Maximum weight loss in hydrogen was 0·29 per cent., after correcting for carbon loss.

(4) A shrinkage of 1·2-1·5 per cent. was obtained by sintering for 45 minutes at 2275°F. (1245°C.).

(5) Qualitative data on green strength led to the conclusion that a compacting pressure of 40 tons per sq. in. will produce compacts which will withstand ordinary commercial abuse.

(6) Since the powdered steel parts are sintered in a highly reducing atmosphere, they are slightly more susceptible to corrosion than stainless steel of comparable composition produced by other methods. A short passivation treatment in nitric acid, followed by a water wash, suffices, however, to correct this limitation.

By varying the compacting pressure, sintering temperature, and coining pressure, it is possible to vary the properties of the compacts over a wide range, thus making the materials suitable for many applications. An outstanding quality of stainless-steel powder parts is their resistance to wear and galling.

A major application of stainless-steel powder in the engineering field has been for small driving arms used in the intermediate gear trains of water meters, and powder-produced steel has also replaced cold-drawn stainless-steel tubing for sleeve bearings and bushings in some industrial meters used for measuring nitric acid and other corrosive liquids. Other applications include guides for fishing rods and small gears, cams and levers in various mechanisms.

Cost of production and lack of suitable press capacity are still limiting factors in development of stainless-steel powder parts, but it is anticipated that once the quantity is sufficiently large to absorb a greater proportion of production costs applications will markedly increase. Due to the negligible scrap loss and the reduction in machining required, the final cost of powder-produced parts is stated to be even now competitive with that of parts made by other processes.

Nickel-Clad Steel Equipment in Production of Pliofilm

See abstract on p 95.

PATENTS

Extraction of Nickel from Silicate Ores

Powdered nickel silicate ore in which the iron:nickel ratio is at least 3·0 is smelted with a flux and a reducing agent (aluminium-silicon, iron-silicon, aluminium-silicon-iron), in amount calculated to reduce all the nickel and only part of the iron in the ore to metal, forming a nickel-iron alloy containing over 30 per cent. of nickel. The process is stated to be suitable for treatment of low- and medium-grade silicate ores.

L. J. LICHTY, assignor to QUEBEC METALLURGICAL INDUSTRIES, LTD. *U.S. Pat.* 2,573,153.

Extraction of Nickel from Arseniferous Ores

Nickel and cobalt are extracted from arseniferous ores by heating at 800°-900°C. with alkali nitrate and carbonate in a reverberatory furnace under oxidizing conditions. The resulting sintered product is treated by wet methods, to separate the oxides of cobalt and nickel and the alkali arsenates formed.

BOZEL-MALETRA (Inventor: A. BELTZER). *French Pat.* 995,987.

Production of Nickel Formate

Finely divided nickel is stirred with formic acid, at 90°-110°C., until a substantial amount of solid nickel formate is precipitated, and the product is separated from the slurry, e.g., by allowing the nickel to settle and decanting off. The process may be continuously operated.

I. E. JOHNSON, assignor to HARSHAW CHEMICAL CO. *U.S. Pat.* 2,576,072.

Preparation of Stable Solutions of Complex Nickel Cyanides

Stable solutions of complex Ni (I) cyanides, e.g., $K_2Ni(CN)_3$, are made by reacting complex cyanides of Ni(II), e.g., $K_2Ni(CN)_4$, with a metallic carbonyl, especially nickel carbonyl, or with carbon monoxide and a metal powder which will form a carbonyl, in the presence of an alkali metal hydroxide.

BADISCHE ANILIN- UND SODA-FABRIK. *French Pat.* 998,299.

Preparation of Nickel-containing Catalysts

Foraminate catalysts, containing one or more of the metals copper, cobalt, nickel, iron, are made by treating an alloy of these metals with silicon or aluminium, at a temperature above 100°C., with a phenol or a monohydric aliphatic alcohol containing not more than 4 carbon atoms, to extract a portion of the silicon and/or aluminium. Total removal may not exceed 70 per cent. by weight of the initial content of these metals. Suitable alloys for such treatment include aluminium-nickel (30-65 per cent. nickel), and silicon-nickel (30-85 per cent. nickel).

P. W. REYNOLDS, A. L. CHALLIS and IMPERIAL CHEMICAL INDUSTRIES, LTD. *Brit. Pat.* 644,851.

Production of Nickel Powder

Metal powders, e.g., copper, nickel or cobalt, are made by precipitating the hydroxides or basic salts of the metals from metal-salt solutions with ammonia or ammonium carbonate, and reducing them at raised temperatures, suitably with hydrogen and, if necessary, under pressure.

BADISCHE ANILIN- UND SODA-FABRIK (I.G. FARBENINDUSTRIE A.G.). *French Pat.* 999,592.

Nickel-Coated Aluminium-base Products

The patent covers a process for production of a ductile composite. It has been found that when nickel is electrodeposited on aluminium or a ductile aluminium alloy, the ductility of the composite product at first decreases but afterwards increases as the nickel layer becomes thicker.

In accordance with this discovery, the invention comprises an aluminium or aluminium alloy sheet (e.g., 0·02 to 0·04 in. thick) having an electrodeposited nickel layer (0·003 to 0·004 in. thick) on one or both sides. The tensile strength of the composite is about twice that of the unclad aluminium base. A final facing of chromium (0·0002-0·0003-in. thick) may be electrodeposited. The preferred process of preparation of the basis material and electrodeposition procedure are covered.

MOND NICKEL CO., LTD. *Brit. Pat.* 667,339.

Electrodeposition of Ductile Nickel Coatings

Nickel coatings sufficiently ductile to be drawn are produced by deposition from an aqueous bath containing a nickel salt, hydrofluoric acid, and boric acid. The hydrofluoric-acid content is greater than that required to form complex nickel fluoride, and should be such as to ensure pH of 1-6. Specific recommendations are for at least 30 (preferably 42-60) g./L. of nickel metal, and preferably 20-60 g./L. of boric acid. The bath is worked at 40°-75°C.

E. L. A. CAMIN, S. E. HYBINETTE and H. B. TAYLOR, assignors to KENMORE METALS CORPN. *U.S. Pat.* 2,576,922.

Activation of Chromium Surfaces for Plating

A chromium-plated surface is activated for further plating by making it the cathode in an aqueous solution containing nickel sulphate and hydrochloric acid, and passing direct current from a nickel anode. Full details of operating conditions are covered.

R. M. WAGNER, assignor to GENERAL MOTORS CORPN. *U.S. Pat.* 2,574,305.

Plating of Rods and Wires

Plated rod or wire which can be drawn down without cracking of the plating is made by forming on the core successive layers of plated metal separated by layers of weakness which permit the metal layers to slip in relation to one another on extension of the rod. Examples cited include nickel-plated steel and copper-plated nickel-iron alloy.

KENMORE METALS CORPN. *Brit. Pat.* 663,044.

Wear-Resistant Nickel-Alloy Coatings for Piston Rings

A hard, wear-resistant nickel-phosphorus, cobalt-phosphorus, or nickel-cobalt-phosphorus alloy coating is deposited chemically from a nickel hypophosphite bath, on one or both side walls of piston-ring grooves.

D. L. GARLAND and R. D. GRAY, assignors to WRIGHT AERONAUTICAL CORPN. *U.S. Pat.* 2,575, 214.

Nickel-Copper Underlay in Chromium Plating of Zinc

An underlay of a nickel-copper alloy is electrodeposited on zinc-base materials from an alkaline phosphate bath of which the following is a typical composition:—

	g.
$NaOH$	100
$NiSO_4$	10
$CuSO_4$	2
Na_3PO_4	30
$NaCN$	10
Na_2SO_4	50
Made up to 1 litre	

STÉ. INDUSTRIELLE DE FOURNITURES POUR L'ELECTROLYSE *French Pat.* 992,626.

Stripping of Electrodeposited Metal Coatings

Coatings of nickel, copper, chromium, zinc, cadmium, tin, and silver are removed from a base of brass, zinc-base die castings, aluminium, or steel, by making the coated metal the anode in a bath containing (1) orthophosphoric acid 64-90, acetic acid 5-14, water 5-24, per cent. by weight, *or* (2) orthophosphoric acid 61-86, sulphuric acid 5-12, acetic acid 3-6·5, water 6-25, per cent. by weight.

H. G. ORLIK, assignor to RADIO CORPN. OF AMERICA. *U.S. Pat.* 2,578,898.

Age-Hardenable Copper-Nickel Alloys

(*a*) Age-hardening treatment for copper-base alloys containing nickel 10-25, manganese 10-25, silicon 0·1-1, per cent. consists in quenching from a temperature between 600° and 925°C. (preferably between 850° and 925°C.), forming by cold working, and hardening by heating at 350°-500°C. (preferably 400°-475°C.) for not less than half an hour, and preferably more than 1½ hours.

A. MORRIS, assignor to BRIDGEPORT BRASS CO. *Canad. Pat.* 478,288.

(*b*) A related patent covers alloys containing nickel 14-25, manganese 14-25, aluminium 0·5-3, per cent., balance copper, which are precipitation-hardened by quenching from 600°-925°C., cold-working, and heating at 350°-500°C. for not less than half an hour.

A. MORRIS, assignor to BRIDGEPORT BRASS CO. *Canad. Pat.* 478,289.

(*c*) A third patent in the group covers alloys containing both silicon and aluminium, viz., nickel 5-25, manganese 5-25, aluminium 0·25-5, silicon 0·05-1, per cent., balance copper. The minimum silicon content varies between 0·1 and 0·05 per cent. in inverse proportion as the aluminium goes from 0·25 to 1 per

cent., and the minimum aluminium present varies between 1 and 0·25 per cent. inversely as silicon varies between 0·05 and 0·1 per cent. Quenching, cold-working and precipitation-hardening treatments are also claimed.

A. MORRIS and H. V. BLOMQUIST, assignors to BRIDGEPORT BRASS CO. *Canad. Pat.* 478,290.

Nickel Additions to Lead

Effect of tin, arsenic and cadmium, in lowering the flash point of lead, is counteracted, and the flash point may even be raised, by the presence of small amounts of nickel (e.g., up to 0·10 per cent.).

H. J. ENTHOVEN AND SONS, LTD., L. F. TAYLOR and P. W. WRIGHT. *Brit. Pat.* 666,956.

Fluxes for Welding High-Nickel Alloys

In gas-welding alloys of high nickel content the flux used is a mixture consisting, by weight, of barium fluoride 40-70, calcium fluoride 10-40, barium chloride 10-20, sodium fluoride 0-15, water-dispersible organic binder 2-10, per cent.

MOND NICKEL CO., LTD. *Brit. Pat.* 662,493.

Sintered Powder-Metal Magnet Alloys

British Patent 659,998 (see *Nickel Bulletin*, 1952, vol. 25, No. 1, p. 30) covers a process for treating sintered compacts for permanent magnets in a non-oxidizing atmosphere. Pick-up of carbon and nitrogen is prevented by embedding the compact in a mass of powdered alloy containing titanium or other element having a high affinity for carbon and nitrogen, and aluminium and/or another metal readily oxidizable at high temperatures. The present patent covers an improvement in the process, effected by inclusion, in the sintered compact (nickel-aluminium-cobalt-iron alloy) of a small proportion of a substance having a strong affinity for carbon, e.g., titanium, niobium, vanadium, boron, zirconium, or any of the rare-earth metals. Alloys or hydrides of such metals may be used.

MUREX, LTD. (Inventor: S. J. GARVIN).
Brit. Pat. 663,067 (Patent of addition to *Brit. Pat.* 659,998).

Production of Anisotropic Nickel-Alloy Magnets

Nickel-containing anisotropic magnets are made by casting a melt as a body having a length:diameter ratio not more than 5:1, in a mould with a chill at one end and heat-insulated sides. Such a casting is heat-treated in a magnetic field, in the direction of its longitudinal axis. The range of composition is given as cobalt 16-30, nickel 12-20, aluminium 6-11, per cent., balance iron.

D. G. P. EBELING, assignor to GENERAL ELECTRIC CO. *U.S. Pat.* 2,578,407.

Preparation of Nickel-Cobalt-Iron Alloys for Sealing into Glass

Alloys of Kovar type are prepared for use as sealing materials by a cycle of treatments: (1) heating in an inert atmosphere, (2) displacing this atmosphere by a reducing one, (3) replacing this by an inert atmosphere, (4) displacing this by an oxidizing atmosphere, and (5) finally cooling in an inert atmosphere. The reducing atmosphere is preferably wet hydrogen, used at 900°-1100°C.

R. O. MCINTOSH, assignor to WESTINGHOUSE ELECTRIC CORPN. *U.S. Pat.* 2,575,724.

Nickel-Iron Alloy Compensating Hairsprings for Watches

Hairsprings are made from an alloy containing nickel 29-42, chromium 4-10, tungsten 1-5, manganese+silicon 0·5-5, carbon 0·5-1, niobium 0·1-5, per cent., balance iron. With niobium contents of 0·1-1·5 per cent. the springs are perfectly isochronous: with 1·5-5 per cent. niobium there is a slight gain. Vanadium (0·1-2 per cent.) may also be present.

E. DUBOIS. *Brit. Pat.* 648,341.

Creep-Resisting Nickel-Chromium-Cobalt-Iron Alloys

Alloys claimed to have good high temperature creep resistance are of the following composition:—Carbon 0·01 to 0·30, chromium 15·0 to 25·0, nickel 8·0 to 20·0, titanium 0·4 to 3·0, cobalt less than 20·0, per cent., balance iron. Tungsten or molybdenum may be added in amounts up to 5 per cent.

Properties are given for such materials in the condition produced by heating at 1150°C. for 15 minutes, followed by water quenching.

STÉ. ANON. ÉTABS. JACOB HOLTZER.
French Pat. 995,494.

Creep-Resisting Materials having Controlled Ratios of Alloy Addition

(*a*) Improved high-temperature alloys, suitable for gas-turbine components, comprise nickel-chromium-cobalt-base alloys containing critically controlled additions of molybdenum, aluminium and titanium, viz., cobalt 10-40, chromium 10-30, molybdenum 2·0-18, aluminium 0·2-8·6, titanium 0·2-4·4, per cent., balance nickel and deoxidants. The following proviso is made:—

$$(1\times\%\ \text{Mo}+2\times\%\ \text{Al}+4\times\%\ \text{Ti})=16\text{-}20.$$

Nickel may be replaced by vanadium up to 10 per cent., and provision is also made for the presence of small amounts of niobium, manganese, silicon, iron, carbon and nitrogen: the iron content should be kept as low as possible. The alloys are treated by heating at 1050°-1250°C. for 2-20 hours, followed by reheating at 700°-1000°C. for 2-50 hours. Properties typical of alloys so treated are cited.
Brit. Pat. 666,399.

(*b*) A further patent covers improvement in casting properties of alloys of the above type (with only slight loss of creep properties), by omission of titanium. It is specified that $(1\times\%\ \text{Mo}+2\times\%\ \text{Al})=12\cdot5\text{-}19$. The basic constituents are somewhat changed in amount: cobalt 10·1-25, chromium 16-25, molybdenum 1-7, aluminium 3-7, per cent.
Brit. Pat. 666,400.

(*c*) A third patent in this group relates to hard nickel-chromium-base alloys having good wear-resisting qualities, claimed to be suitable for tools, extrusion

dies, and wire-drawing dies. Range of composition: chromium 16-25, cobalt 0-40, molybdenum 3-17, aluminium 3-9, titanium 0-4, per cent., balance nickel, with the proviso that

$$(1\times\%\ \text{Mo}+2\times\%\ \text{Al}+4\times\%\ \text{Ti})=19\text{-}25.$$

Other elements may also be present, as in 666,399 above. Details of solution and ageing treatment are also covered.

Brit. Pat. 666,401.

ROLLS ROYCE, LTD. (Inventors: H. E. GRESHAM, A. DUNLOP and M. A. WHEELER).

Nickel-base High-Temperature Alloy

A preferred alloy within the following composition range is claimed to have a 100-hour rupture strength of 50,000 p.s.i. (22·3 tons per sq. in.) at 1500°F. (815°C.), and an elongation of 5 per cent. on 2 in. Composition range (preferred figure shown in brackets):—chromium 5-20 (5-10), molybdenum 5-15 (5-10), aluminium 4·5-6 (6), niobium about 2 (2), boron about 0·5 (0·5), carbon about 0·1 (0·1), per cent., balance cobalt and nickel, the cobalt being not more than 20 per cent.

A. G. GUY, assignor to GENERAL ELECTRIC CO. *U.S. Pat.* 2,575, 915.

Deoxidation of Nickel-Chromium Electrical-Resistance Alloys

Nickel-chromium and nickel-chromium-iron alloys are deoxidized by additions of sodium, potassium, rubidium or caesium, preferably added as an alloy with calcium. The melt may be given a preliminary deoxidation by other means prior to such treatment. Typical ranges of composition for the alloys treated, and of permitted residual amounts of the treating elements, are specified. The patent covers nickel-chromium- and nickel-chromium-iron alloys in which additions of tungsten, molybdenum, manganese, cobalt, zirconium and other metals may be present.

BRITISH DRIVER HARRIS CO., LTD. and W. F. MARSH. *Brit. Pat.* 666, 071.

Descaling of Stainless Steels

Descaling treatment for stainless steels comprises dipping in a fused sodium-hydroxide bath, pickling in dilute aqueous sulphuric acid, and finally dipping in dilute aqueous nitric acid. The sodium-hydroxide bath may contain 0·5-3 per cent. of sodium peroxide, and a small amount of hydrofluoric acid may be added to the nitric-acid bath.

C. B. FRANCIS, assignor to UNITED STATES STEEL CO. *U.S. Pat.* 2,569,158.

Pickling of Stainless Steels

An aqueous pickling solution for stainless steels contains, in amounts based on the weight of the solution, about 5-20 per cent. of nitric acid, 1-5 per cent. hydrofluoric acid, and 0·001-3 per cent. of a glycol ether of an ethanol rosin amine.

E. A. BRIED, assignor to HERCULES POWDER CO. *U.S. Pat.* 2,564,749.

Blackening Treatment for Nickel-Alloy Steels

A mixture of an alkali metal salt of an aryl sulphone monochloramide (preferably benzene or toluene) and 15-125 times as much of an alkali metal hydroxide is dissolved in water, to give a solution boiling at 250°-300°C. The metals to be blackened are immersed in the boiling solution. It is claimed that such treatment satisfactorily blackens plain steels, low-alloy nickel-containing and other alloy types, and the straight-chromium grades of stainless steel.

I. L. NEWELL. *U.S. Pat.* 2,579,752.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks*.

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